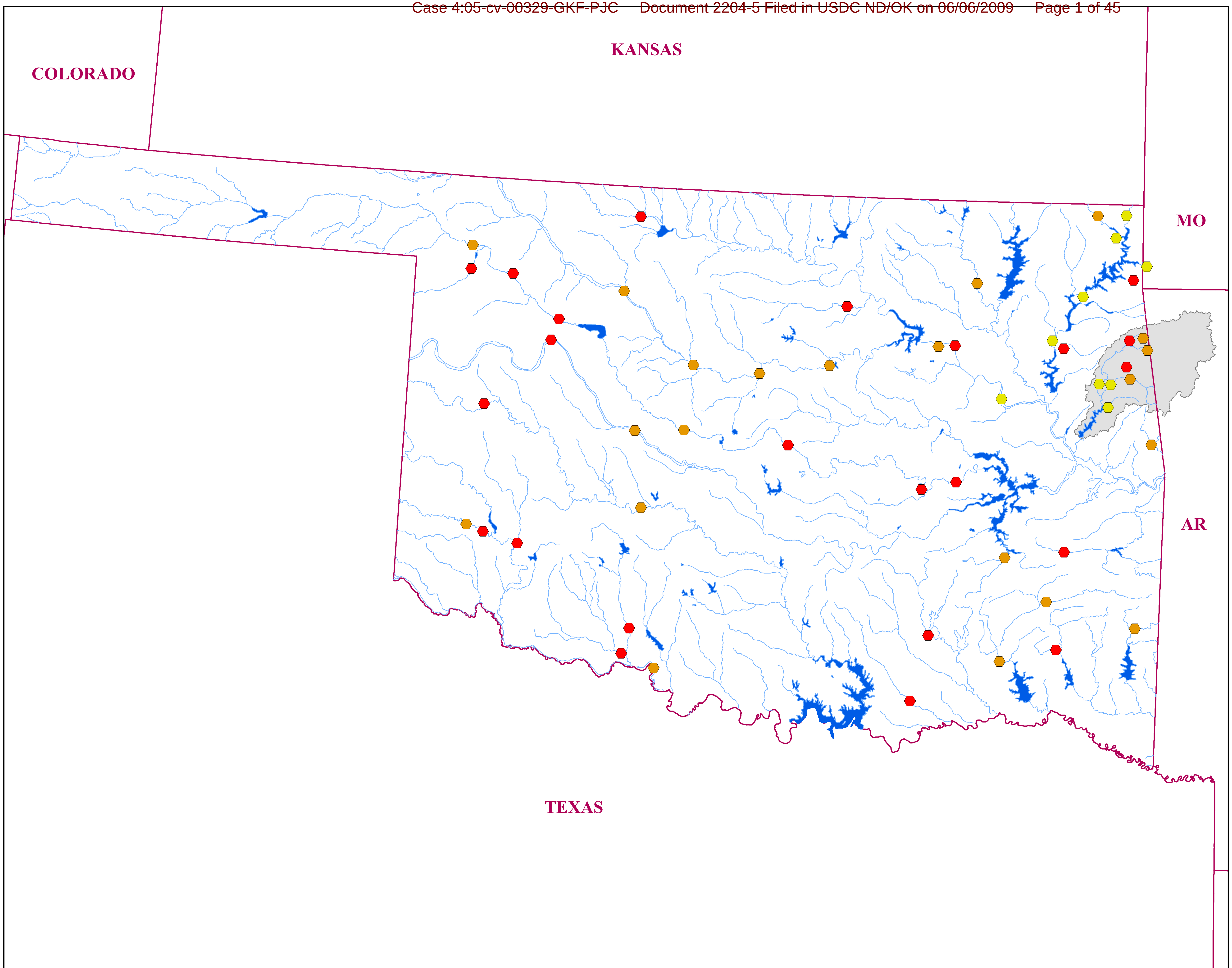
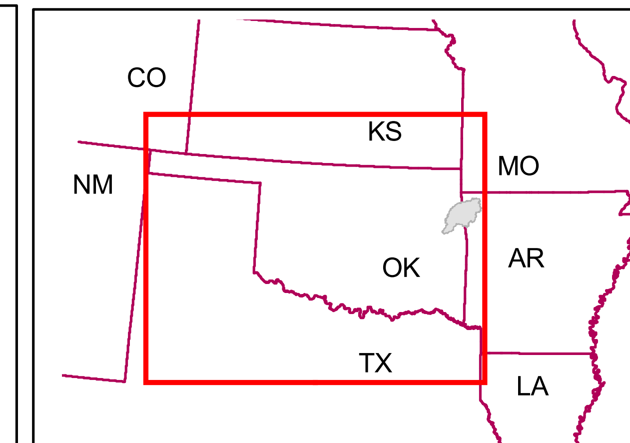




Locator Map

Legend

Enterococci

- < 33 (1<x threshold)
- 33 - 66 (1-2x threshold)
- 66 - 164 (2-5x threshold)
- >= 164 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

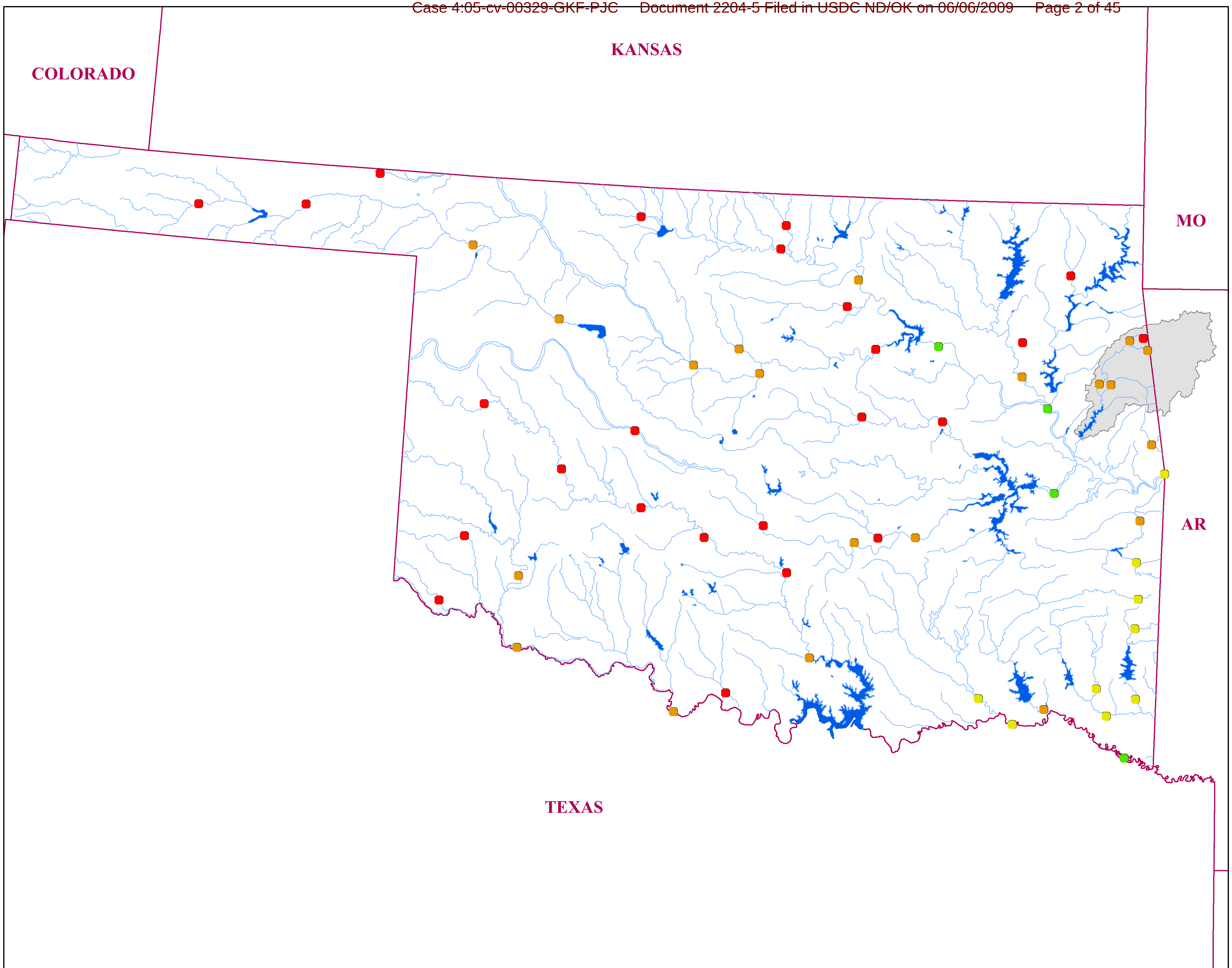
Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

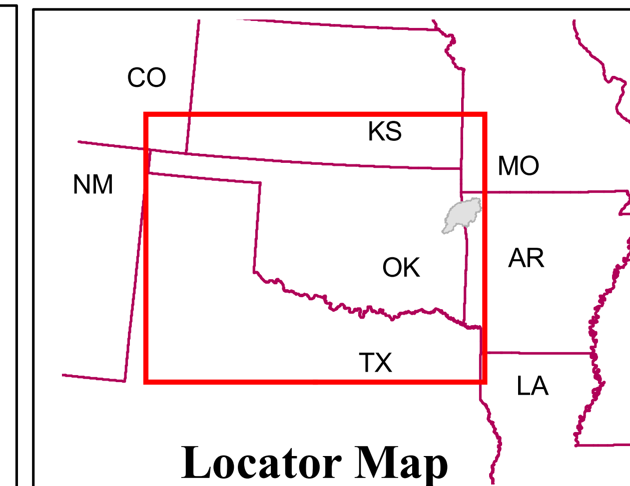
Figure 6-5a.
2003 Enterococci seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009





Locator Map

Legend

Enterococci

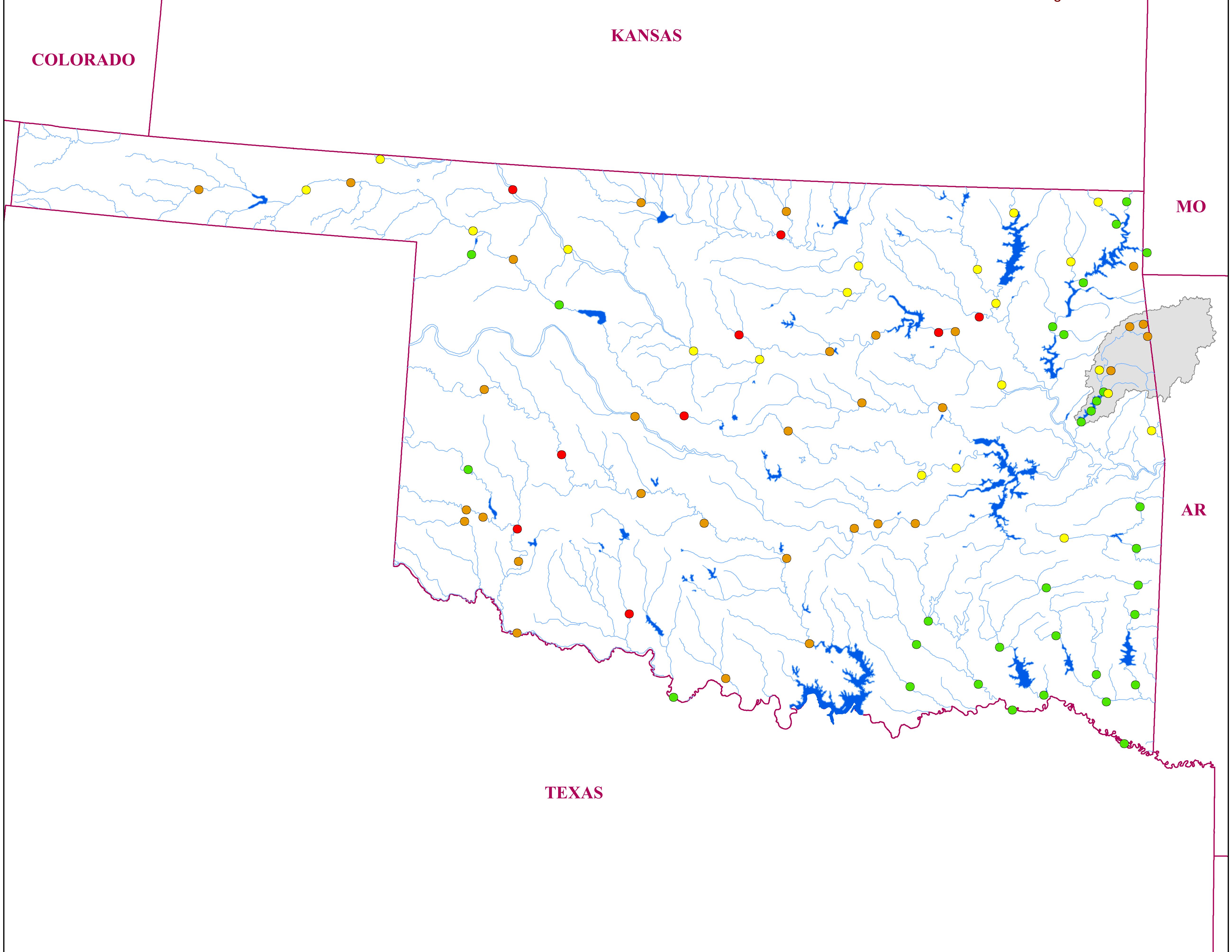
- < 33 (< 1x threshold)
- 33 - 66 (1-2x threshold)
- 66 - 164 (2-5x threshold)
- >= 164 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

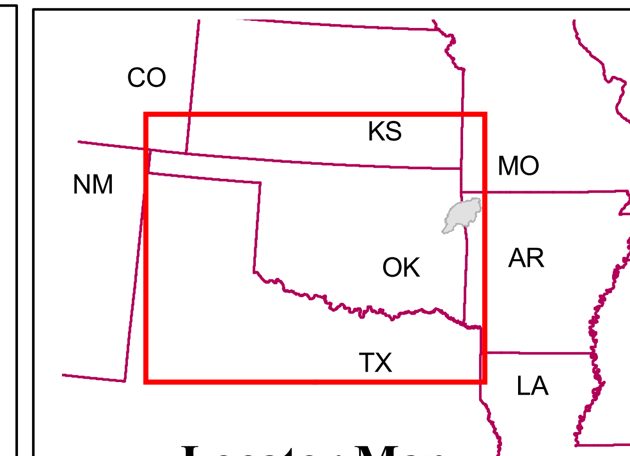
Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5b.
2004 Enterococci seasonal geometric mean counts at sampling locations throughout Oklahoma.

OICiln:114

January 2009





Locator Map

Legend

Enterococci

- < 33 (< 1x threshold)
- 33 - 66 (1-2x threshold)
- 66 - 164 (2-5x threshold)
- >= 164 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

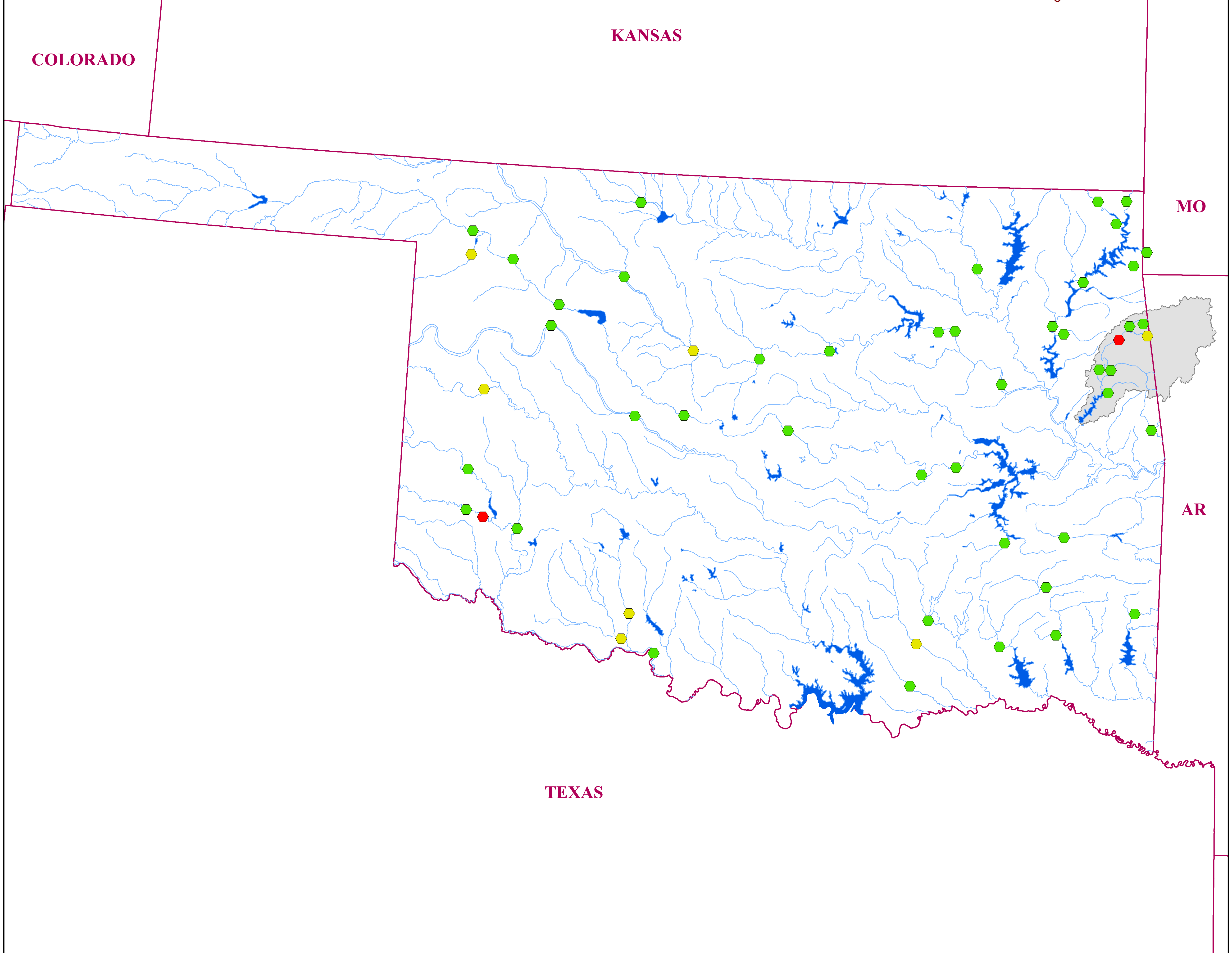
Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

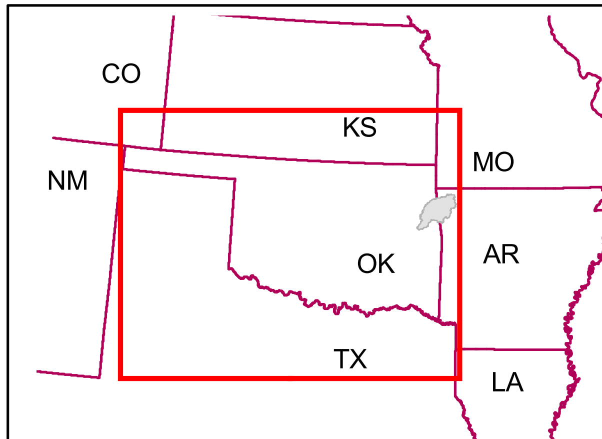
Figure 6-5c.
2006 Enterococci seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICIln:114

January 2009





Locator Map

Legend

E. coli
< 126 (<1x threshold)
126 - 252 (1-2x threshold)
252 - 630 (2-5x threshold)
>= 630 (>=5x threshold)
Rivers
Lakes
Illinois River Watershed

Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5d.
2003 *E. coli* seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009

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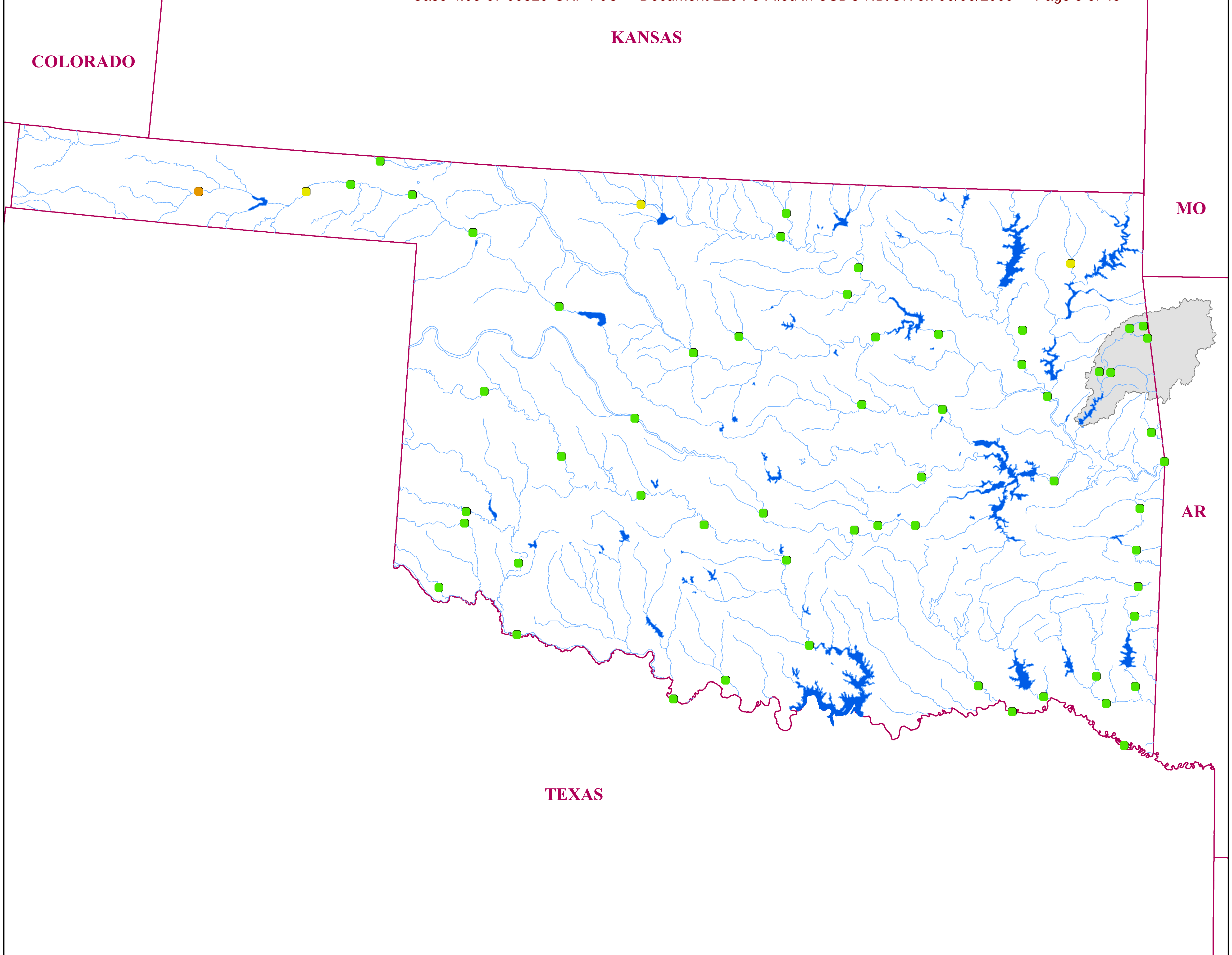

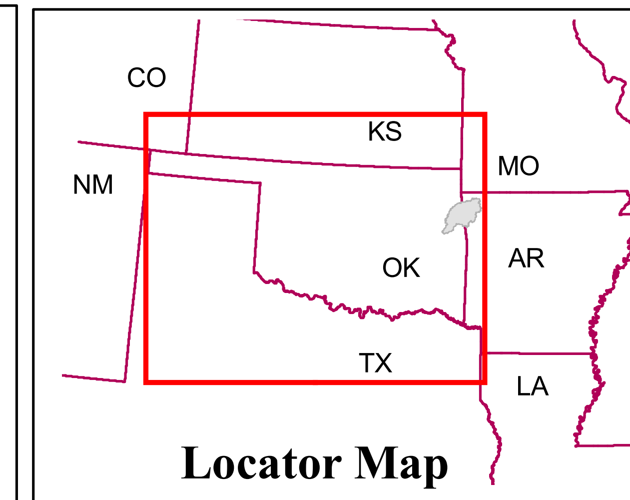

Locator Map

Legend

E. coli

- < 126 (<1x threshold)
- 126 - 252 (1-2x threshold)
- 252 - 630 (2-5x threshold)
- >= 630 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5e.
2004 *E. coli* seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009

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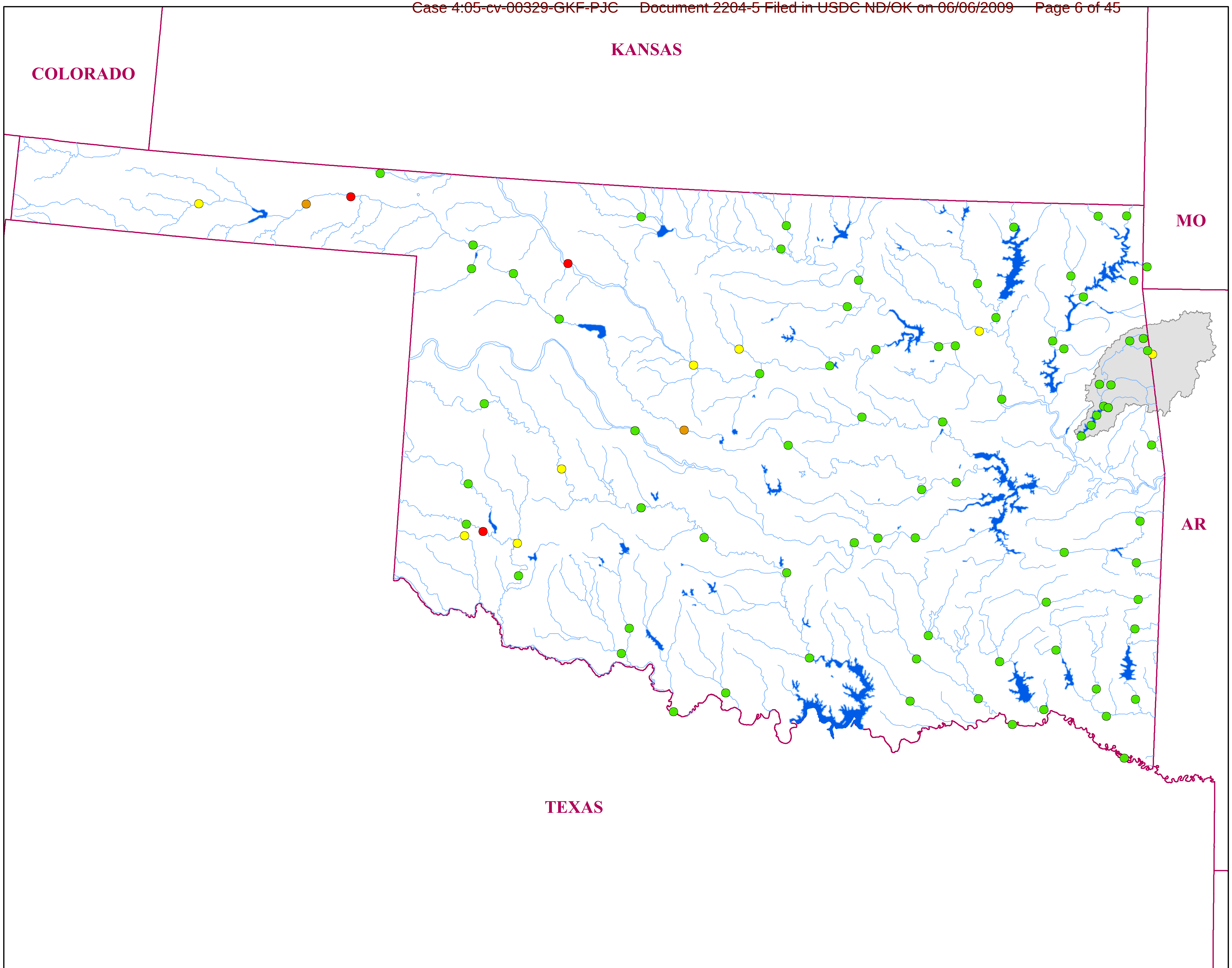

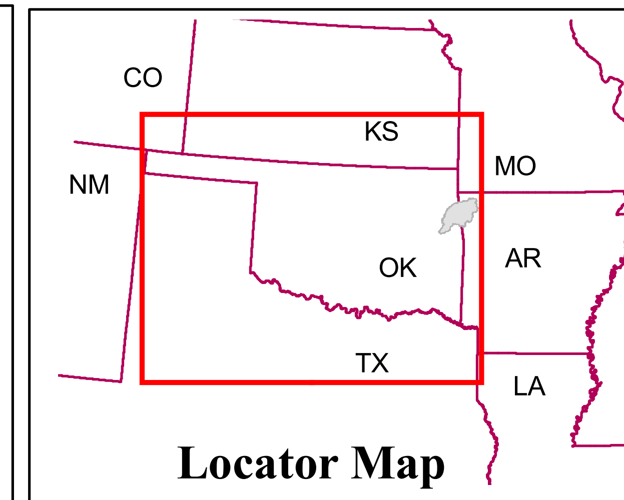

Locator Map

Legend

E. coli

- < 126 (<1x threshold)
- 126 - 252 (1-2x threshold)
- 252 - 630 (2-5x threshold)
- >= 630 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5f.
2006 *E. coli* seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009

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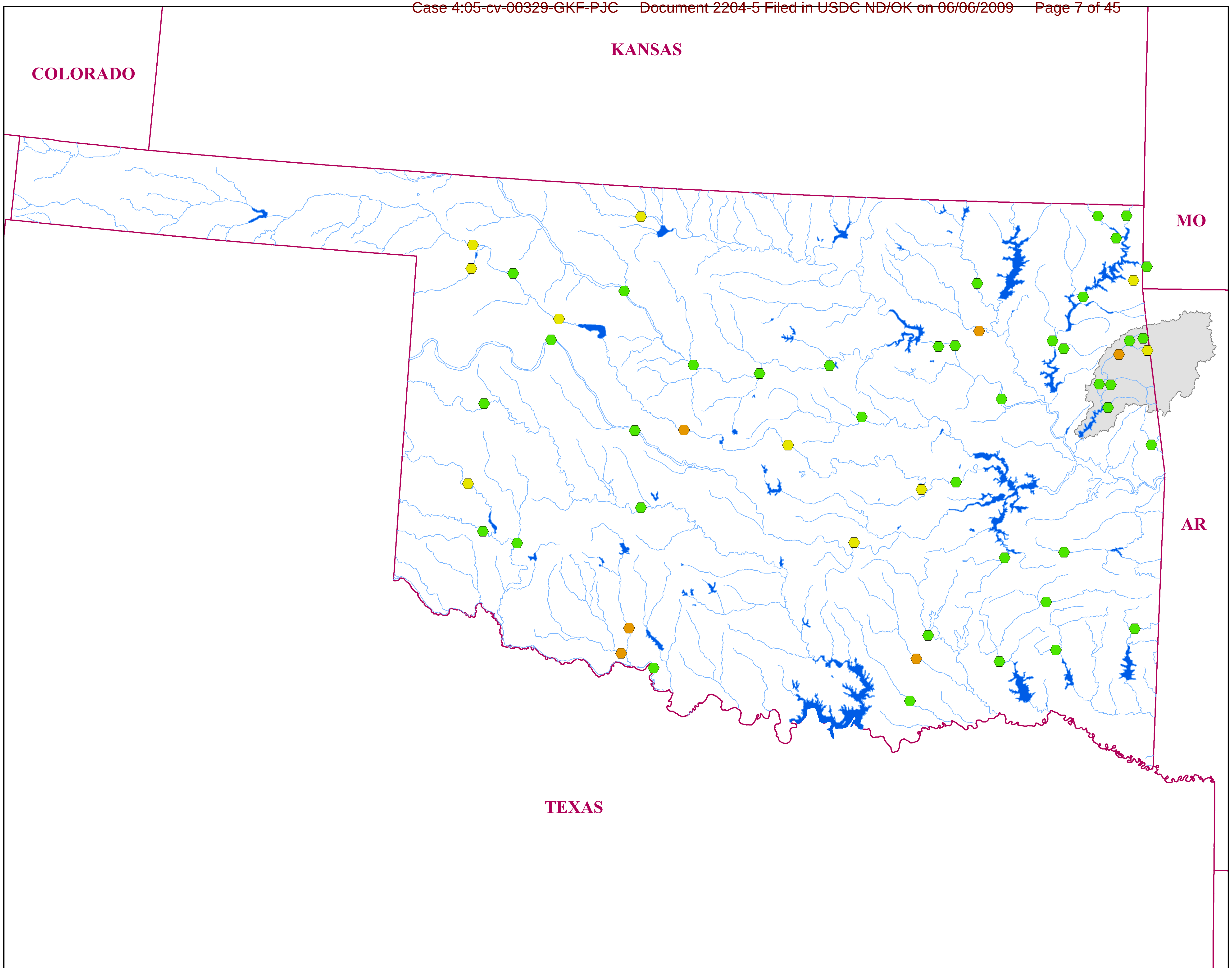
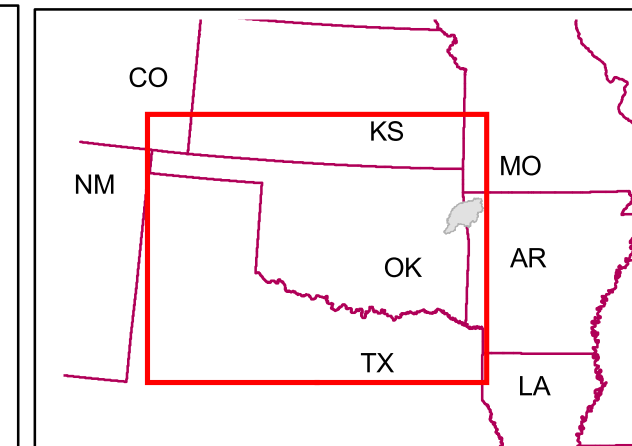




Locator Map

Legend

Fecal Coliform

- < 200 (<1x threshold)
- 200 - 400 (1-2x threshold)
- 400 - 1000 (2-5x threshold)
- >= 1000 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

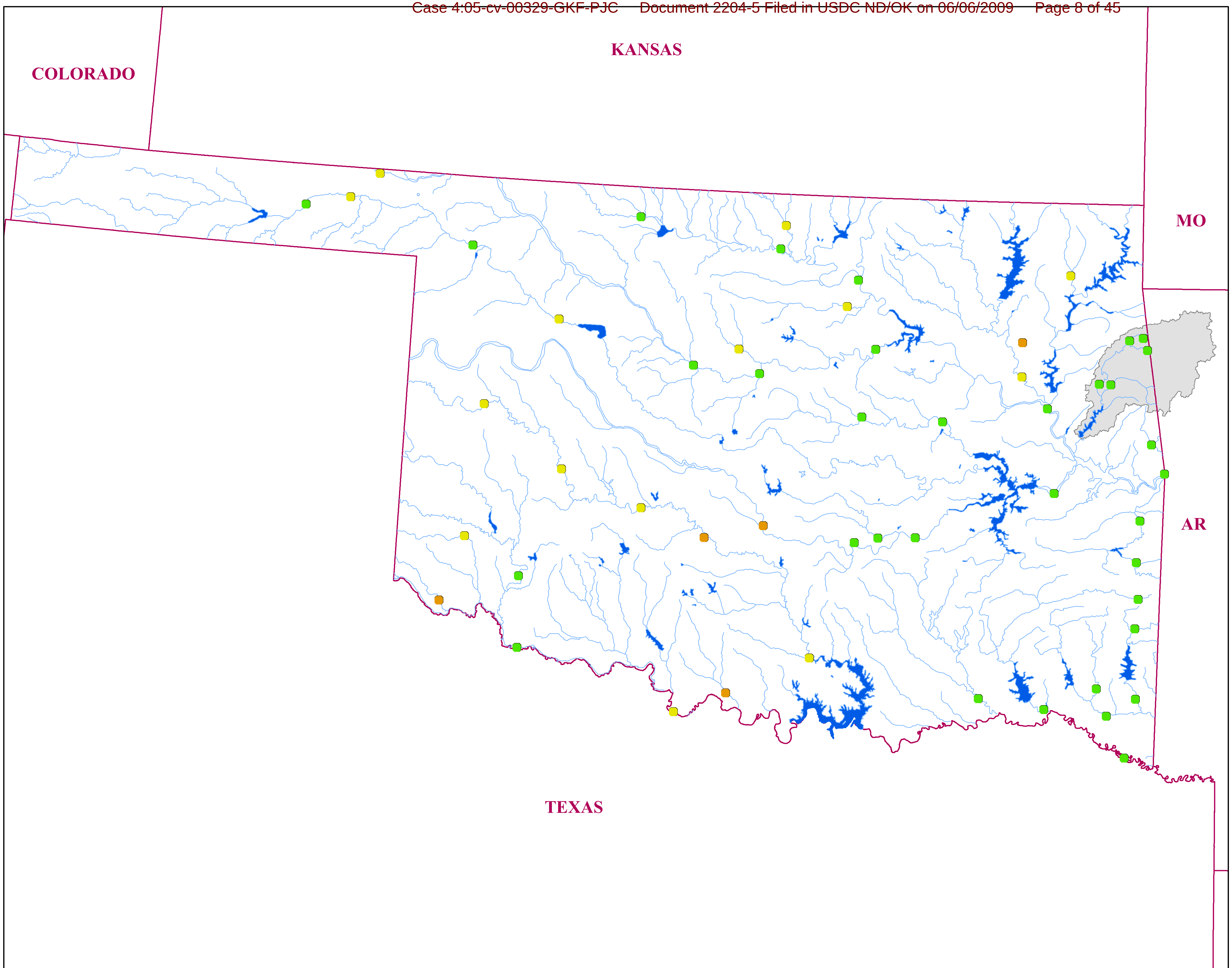
Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

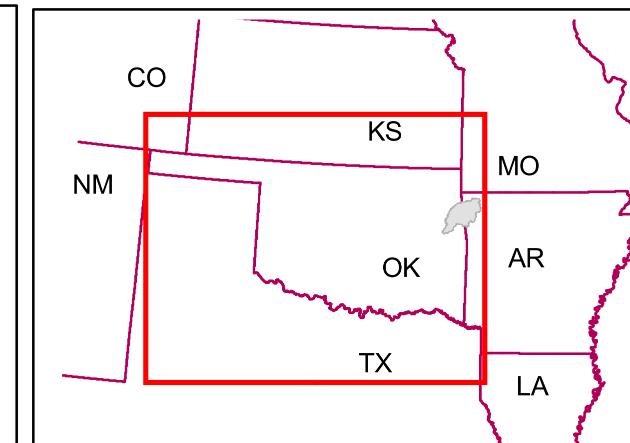
Figure 6-5g.
2003 Fecal Coliform seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009





Locator Map

Legend

Fecal Coliform

- < 200 (<1x threshold)
- 200 - 400 (1-2x threshold)
- 400 - 1000 (2-5x threshold)
- >= 1000 (>=5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5h. 2004 Fecal Coliform seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009

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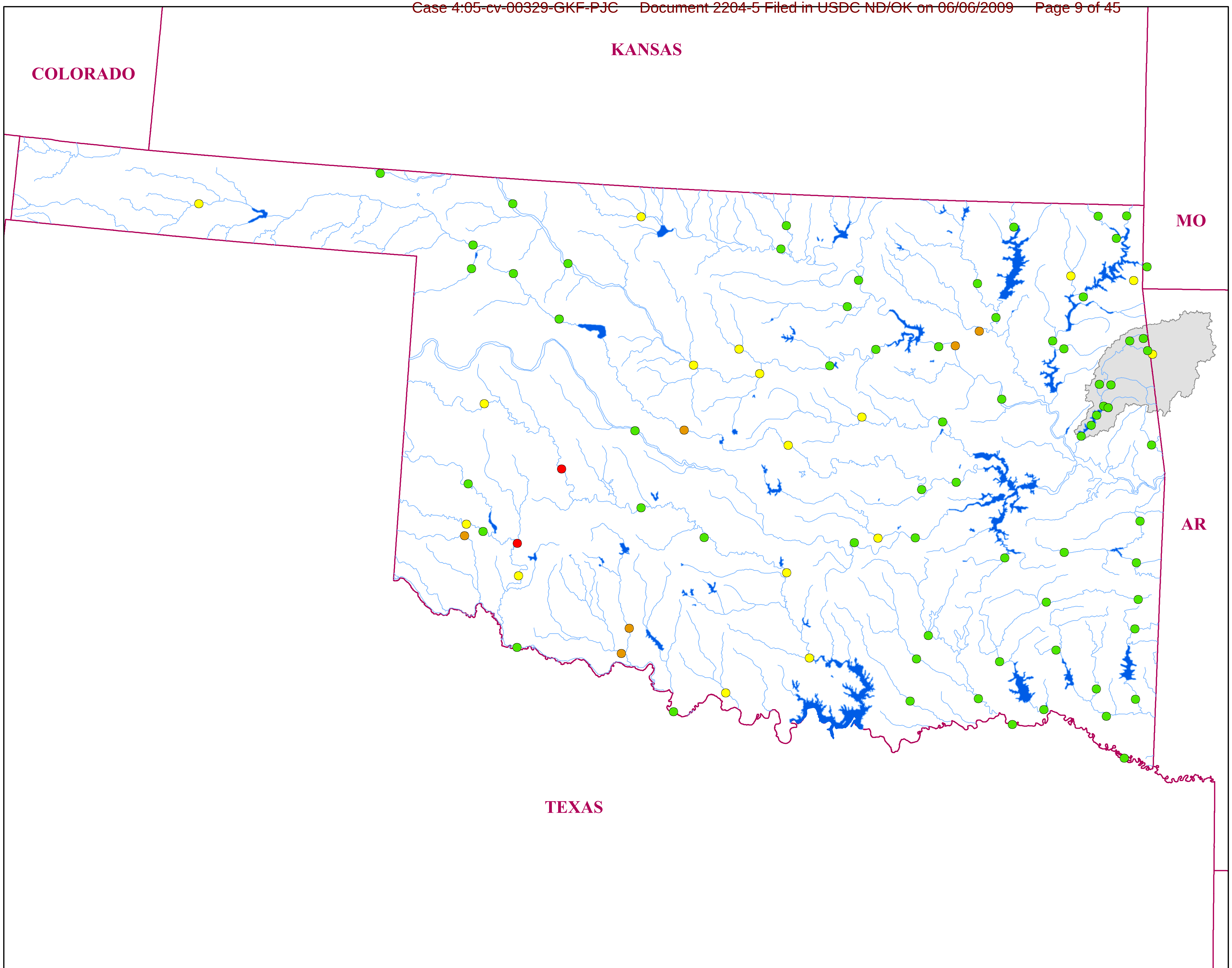

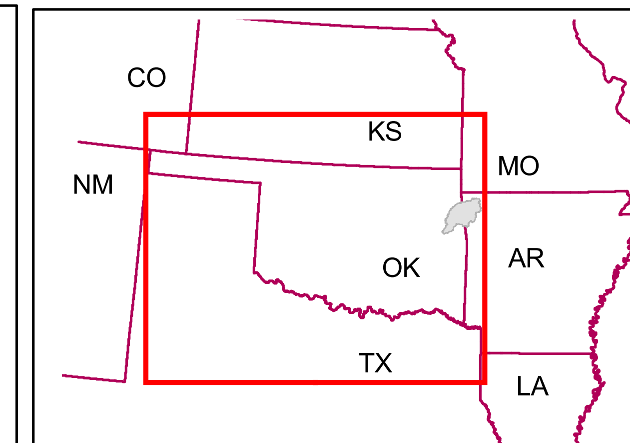

Locator Map

Legend

Fecal Coliform

- < 200 (<1x threshold)
- 200 - 400 (1-2x threshold)
- 400 - 1000 (2-5x threshold)
- >= 1000 (>= 5x threshold)
- Rivers
- Lakes
- Illinois River Watershed

Notes:
1) Data represent the May - September time period.
2) Stations with fewer than 5 data records were omitted.
3) Samples below the quantitation limit were averaged in at the quantitation limit.
4) Units for bacteria are cfu/100 ml or mpn/100 ml.
Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

Figure 6-5i.
2006 Fecal Coliform seasonal geometric mean counts at sampling locations throughout Oklahoma.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009

CALL - \\Frodo\D_Drive\QEA_Syracuse\Jobs\OICiln\GIS\Projects\Chicken\Bacteria_locs_OKstate.mxd

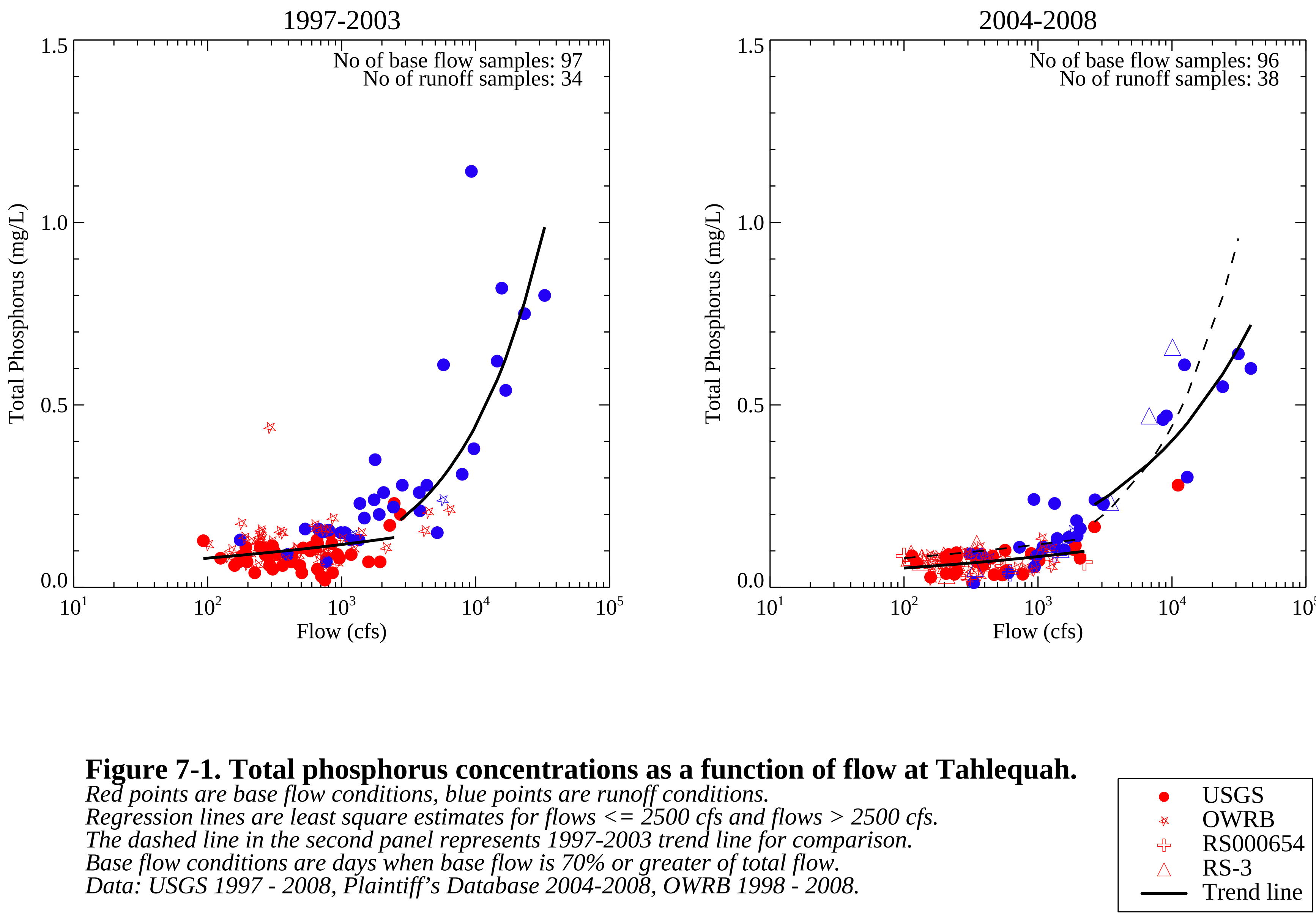

Figure 7-1. Total phosphorus concentrations as a function of flow at Tahlequah.
Red points are base flow conditions, blue points are runoff conditions.
Regression lines are least square estimates for flows <= 2500 cfs and flows > 2500 cfs.
The dashed line in the second panel represents 1997-2003 trend line for comparison.
Base flow conditions are days when base flow is 70% or greater of total flow.
Data: USGS 1997 - 2008, Plaintiff's Database 2004-2008, OWRB 1998 - 2008.

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Thu Jan 22 19:10:10 2009

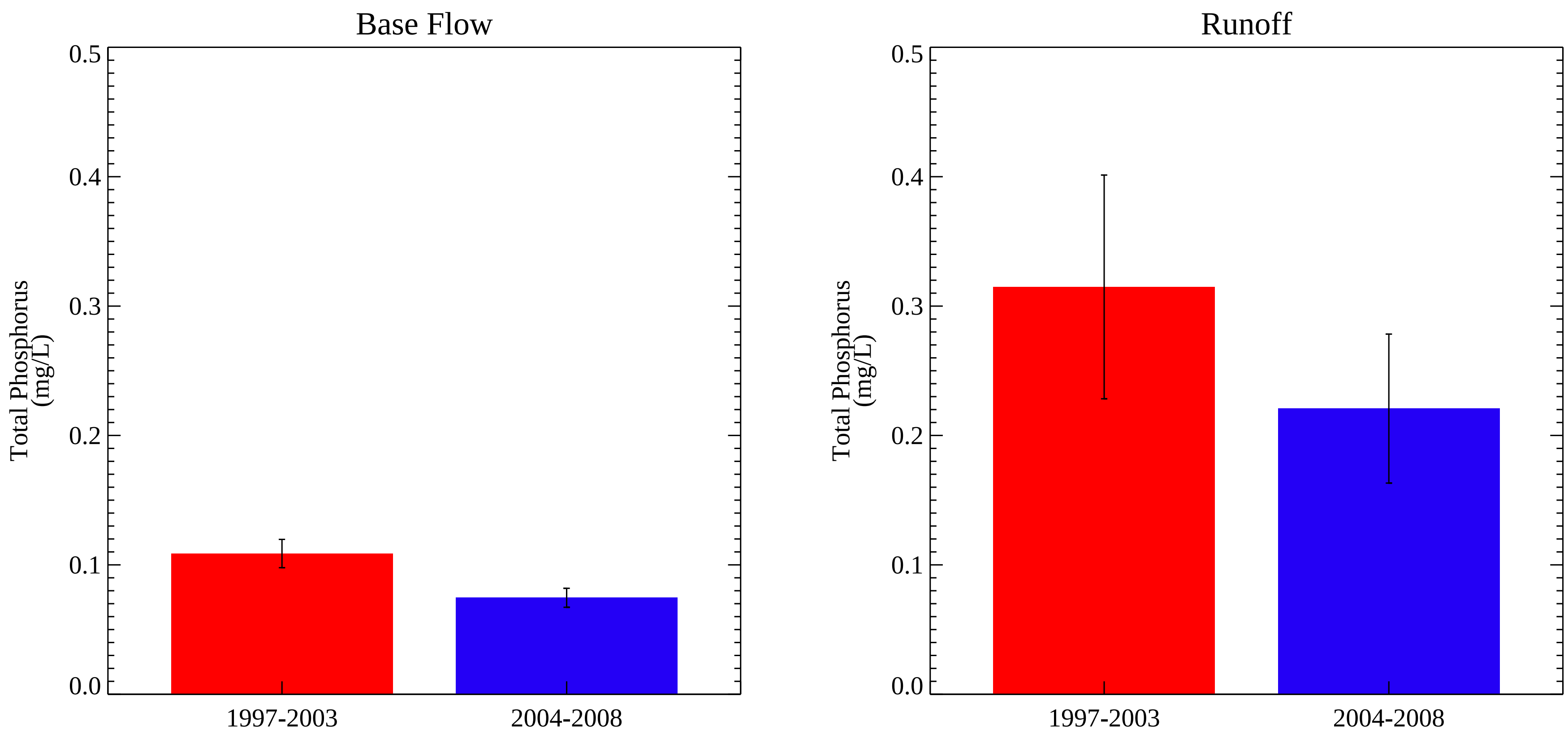

Figure 7-2. Average total phosphorus during base flow and run off events at Tahlequah.
Error bars at +/- 2 standard errors.
Data: USGS 1997-2008, Plaintiff's Database 2004-2008, OWRB 1998-2008.

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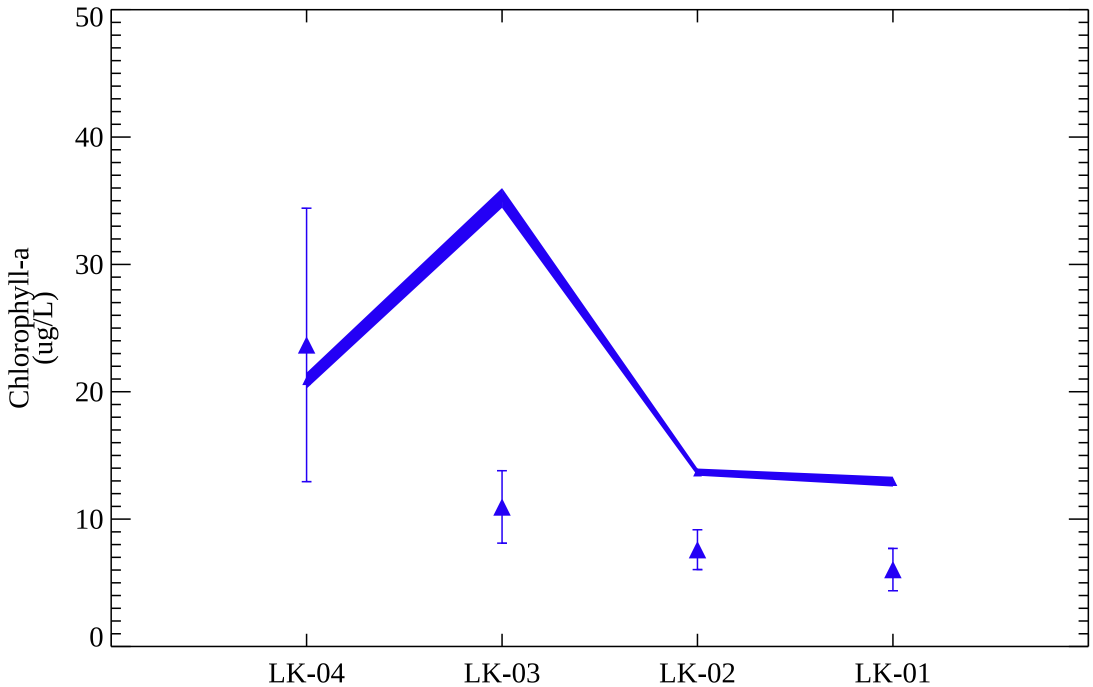
Wed Jan 21 10:16:56 2009



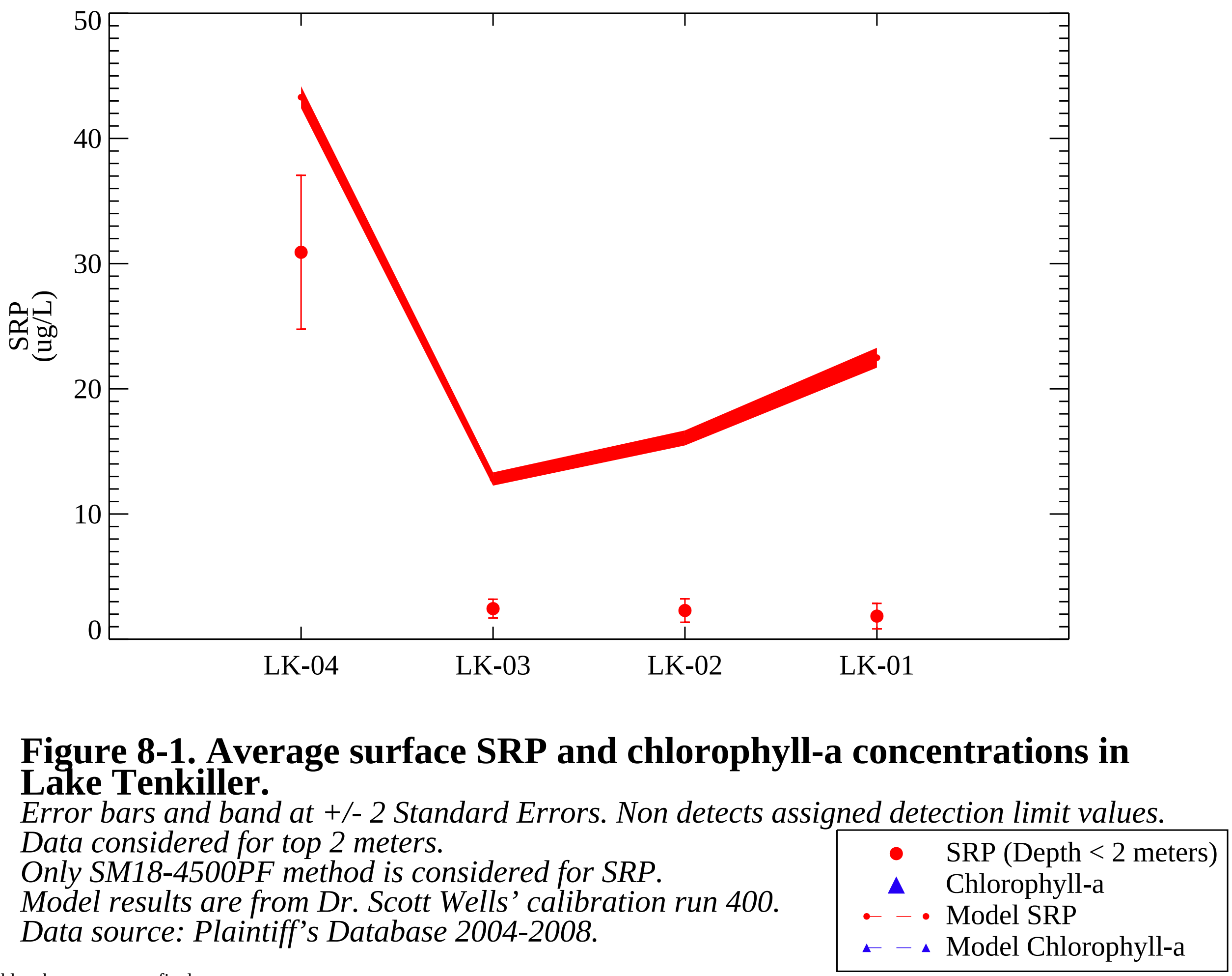


Figure 8-1. Average surface SRP and chlorophyll-a concentrations in Lake Tenkiller.

Error bars and band at +/- 2 Standard Errors. Non detects assigned detection limit values.
Data considered for top 2 meters.
Only SM18-4500PF method is considered for SRP.
Model results are from Dr. Scott Wells' calibration run 400.
Data source: Plaintiff's Database 2004-2008.

RN - D:\OICiln\Analysis\chla_phos_summary_final.pro
Sun Jan 25 16:24:47 2009

APPENDIX A
Full resume of Dr. John P. Connolly

Quantitative Environmental Analysis, LLC
∂c/∂t

JOHN P. CONNOLLY, Ph.D., P.E., BCEE

CONTACT INFORMATION

Quantitative Environmental Analysis, LLC
305 West Grand Ave, Suite 300
Montvale, NJ 07645
(201) 930-9890
(201) 930-9805 *fax*
jconnolly@qeallc.com

PROFESSIONAL HISTORY

Quantitative Environmental Analysis, LLC, President and Senior Managing Engineer, February 1998 to present
USEPA Science Advisory Board, 2005 to present
HydroQual, Inc., Principal Engineer, 1993 to January 1998
HydroQual, Inc., Consultant, 1980 to 1993
Manhattan College, Professor, 1992 to 1994
Manhattan College, Associate Professor, 1986 to 1992
Manhattan College, Assistant Professor, 1980 to 1986
U.S. Environmental Protection Agency, Environmental Scientist, 1978 to 1980
Manhattan College, Research Engineer, 1975 to 1977

EDUCATION

The University of Texas at Austin, Ph.D., 1980
Manhattan College, M.E., Environmental Engineering, 1975
Manhattan College, B.E., Civil Engineering, 1973

REGISTRATION

Professional Engineer, State of Texas (License No. 92122)
Professional Engineer, State of New York (License No. 59428)

EXPERIENCE SUMMARY

Dr. Connolly is a nationally recognized expert on contaminated sediments and eutrophication. His work has been directed to surface water and groundwater contamination problems for the purposes of allocation among potential sources, evaluation of remedial options, remedy design or wasteload allocation (TMDLs). He is expert in water quality modeling and has been involved in the development of several models commonly applied to real world problems. He is also recognized for his ability to communicate complex technical results to the range of stakeholders typically involved in projects and is frequently called on to make presentations at regulatory hearings, community meetings and national and regional technical forums. Dr. Connolly has participated in negotiations with regulatory agencies to craft consent decrees governing contaminated sediment sites.

Dr. Connolly is frequently invited to participate in government and industry sponsored workshops. He is a member of the USEPA Science Advisory Board. He has worked throughout the U.S., in Latin America, and in Europe. He has served as an expert witness for industry and government agencies and has provided testimony before the U.S. Congress and the New York State Assembly. He is also a member of the Manhattan College Council of Engineering Affairs.

RECENT TESTIMONY

NCR Corporation vs. AIG Centennial Insurance Co. et al. – State of Wisconsin Circuit Court Brown County

For plaintiff NCR Corpoations; expert witness testimony at deposition on 12/27/08 regarding whether PCB released up to the early 1970s continued to cause damage to the Lower Fox River and its biota during the insured period.
.

Town of Oyster Bay vs. Northrop Grumman Systems Corp., United States Navy and United States of America – United States District Court, Eastern District of New York

For defendants United States Navy and United States of America; expert witness testimony at deposition on 6/27/07 regarding the likelihood that PCBs in the soils of a town park originated from a site on Grumman property owned by the United States Navy.

Maine Environmental Protection Board.

Expert testimony given on 5/2/07 regarding the deficiencies of a phosphorus, TSS and BOD TMDL developed for Gulf Island Pond on the Androscoggin River and the contributions of various sources to existing algal and dissolved oxygen problems.

Subcommittee on Water Resources and Environment of the U.S. House of Representatives Transportation and Infrastructure Committee Hearing on Strategies to Address Contaminated Sediments.

Expert testimony given on 7/19/01 regarding the approaches used by USEPA to address contaminated sediments.

MAJOR PROJECTS

Contaminated Sediments Assessment and Management

Peer Review of Contaminated Sediment Remediation Guidance for Hazardous Waste Sites

Client: USEPA

One of three national experts tasked with reviewing the draft guidance document which has been developed to provide technical and policy guidance to project managers and management teams making remedy decisions for contaminated sediment sites.

Source Allocation for Mercury in the Penobscot River Estuary

Client: Mallinckrodt, Inc.

Principal investigator for evaluation of the relative contributions of sediment and water column mercury to mercury found in resident biota. This study involved data analysis and development of a conceptual modeling explaining the probable reasons of the apparent lack of impact of elevated sediment mercury concentrations on biota mercury levels. The work was used to provide litigation support through expert testimony. Subsequent to litigation, work has focused on development of a detailed investigation plan, interaction with a court-mandated Study Panel, technical support for the client's legal team and oversight of planned field work.

Source Allocation for Mercury in the Peconic River

Client: Brookhaven National Laboratory

Principal investigator for investigations to determine the sources of methyl mercury in the fish of the Peconic River. This study involved the design of sampling programs and interpretation of data to determine the relative contributions of background sources and various sediment deposits throughout the river to methyl mercury in the water and fish. This work was conducted to satisfy a diverse group of stakeholders with differing positions on appropriate remediation. It led to a revision of the contemplated remedial action and a convergence of opinion on the best approach for the river.

Investigation of Mercury in Lavaca Bay

Client: Alcoa

Principal investigator for the evaluation of mercury sources and prediction of the impacts of remedial actions and storm events on mercury levels in sediment and biota. The project involves data analysis and the development of linked hydrodynamic, sediment transport, mercury fate and bioaccumulation models. A primary goal is the evaluation of the impact of hurricanes and other rare storms on buried mercury.

Remediation of the Hudson River PCBs Site

Client: General Electric Company

Principal investigator for various aspects of remedial design (RD), including the design and execution of an extensive pre-design sediment sampling program involving the collection of more than six thousand sediment cores, management of the RD database, determination of the dredging prisms, design and execution of the baseline and construction monitoring programs and support of the design of dredging and processing of dredged sediment. This project included the development of sophisticated data entry, data processing and data display systems that were used by the GE design team. Additional activities included direct participation in consent decree negotiations.

Analysis of the Fate of PCBs in the Hudson River

Client: General Electric Company

Principal investigator for extensive data analysis and modeling studies of the dynamics of PCBs in the Hudson River. This study involved field sampling, data analysis and the development of linked hydrodynamic, physical/chemical, sediment transport and food chain models for the purpose of predicting the effects of alternative remediation plans.

Analysis of the Fate of PCBs in the Grasse River

Client: Alcoa

Principal investigator for the determination of the impacts of contaminated sediments and point sources to PCB contamination in resident fish. Efforts include the design of field sampling programs, estimation of PCB fluxes between water and sediment, including the importance of areas of elevated concentrations and the transport and bioaccumulation in the food web. Goal is to provide a technical basis for examination of remedial options.

Assessment of Contribution of PCBs to the Kalamazoo River from Eaton Corporation

Client: Eaton Corporation

Principal investigator for the analysis of data and development of models to evaluate whether either or both of two Eaton facilities contributed measurable quantities of PCBs to the Kalamazoo River. The project involved the compilation and analysis of historical data, design and execution of a sampling program and the development of models to predict the transport of sediment and PCBs through the Kalamazoo River.

Analysis of the Fate of PCBs in the Housatonic River

Client: General Electric Company

Technical advisor for extensive data analysis and modeling studies directed to determining the appropriate remedial solution for the contaminated sediments. This study involves data analysis and the development of linked hydrodynamic, sediment transport, PCB fate and PCB bioaccumulation models. An important aspect of this project is the evaluation of the role of river flooding in PCB fate and impact of flood plain soils.

Modeling of Heavy Metal and Organic Contaminant Fate in the Pawtuxet River to Support a RCRA Facility Investigation

Client: Ciba-Geigy Corporation

Principal investigator for determination of target chemicals by qualitative risk analysis, design of a sampling program and development of a model to evaluate temporal and spatial concentration reductions resulting from remedial action alternatives including excavation and groundwater treatment.

Analysis of DDE and PCB Transfer Pathways in the Southern California Bight Ecosystem

Client: National Oceanic and Atmospheric Administration

Principal investigator for the analysis of data and development of food chain models to study the relationship between sediment contamination and levels of DDE and PCBs in fish, mammals, and birds. The purpose of this work was to establish probable sources of contamination in support of a Natural Resource Damages Assessment.

Contaminated Groundwater Assessment and Management

Evaluation of Solvent Plume Migration and Fate at the MW Manufacturing Site, Valley Township of Pennsylvania

Client: Lucent Technologies

Principal investigator for the development and application of flow and transport models to be used to predict the movement and decay of a VOC plume composed of PCE, TCE, 1,2-DCE and vinyl chloride. The goal of the project is to estimate whether the plume has achieved a steady-state configuration in response to a non-aqueous phase source and to project discharge rates to a local stream.

Modeling of Groundwater Remediation Using Vertical Groundwater Circulation Technology

Client: SBP Technologies

Principal investigator for the development of a strategy to model the treatment efficiency of *in-situ* vertical groundwater circulation technology. Work included the evaluation of circulation, nutrient dynamics and PAH biodegradation and volatilization. The goal was to develop a modeling framework that could be used to design sampling strategies and evaluate treatment efficiency.

Total Maximum Daily Load (TMDL) Investigations

Evaluation of the Phosphorus, TSS and BOD TMDL for Gulf Island Pond on the Androscoggin River, Maine

Client: Verso Paper Company

Principal investigator for the critique of the TMDL developed by Maine DEP and the examination of the contributions of point and non-point sources to algal and dissolved oxygen problems in the Pond.

San Francisco Bay PCBs

Client: General Electric Company

Principal investigator for the review and critique of a draft TMDL document issued by the San Francisco Bay Regional Water Quality Control Board. This study involved the analysis of data and modeling to provide the Board with the information necessary to correct deficiencies in the draft document with regard to natural recovery and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the authors of the document.

Coosa River PCBs

Client: General Electric Company

Principal investigator for the review and critique of a draft TMDL document issued by the State of Georgia. This study involved the analysis of data to provide the State with the information necessary to correct deficiencies in the draft document with regard to natural recovery and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the State and with EPA Region 4.

Water Quality/Eutrophication Assessment

Assessment of the Environmental Fate and Impact of ICE-B-GON on Lake Wingra, Wisconsin

Client: Chevron Research Company

Principal investigator for the laboratory determination of the degradation and oxygen utilization kinetics of the de-icing chemical, ICE-B-GON and projection of the effect of the use of this chemical on the dissolved oxygen of receiving waters using Lake Wingra as a case study.

Mathematical Modeling of Water Quality in Lake Erie

Client U.S. Environmental Protection Agency, Grosse Ile, Michigan

Project Engineer in charge of data analysis development and calibration of an eutrophication model including multiple algal species and zooplankton, and projections of the effects of reduction in point and non-point nutrient loadings on pollution indicators; lake phytoplankton, nutrient, and dissolved oxygen levels.

Analysis of Heavy Metals, Ammonia and Cyanide in the Genesee River

Client: Eastman Kodak Corporation

Project Engineer in charge of data analysis, mathematical model development and assessment of the relative impact of the Kodak treatment plant effluent on water quality in the River.

Analysis of the Fate of Toxic Chemicals in Estuaries

Client: U.S. Environmental Protection Agency, Gulf Breeze, Florida

Project Manager in charge of development of a mathematical model describing the transport and degradation of toxic chemicals in estuarine environments.

Development of Version 4.0 of the Water Analysis Simulation Program (WASP)

Client: U.S. Environmental Research Laboratory, Athens, Georgia

The purpose of this project was to modify the USEPA water quality model WASP (3.2) to provide a single modeling framework for use in all types of surface water problems including conventional and toxic pollutants under steady-state or time-variable conditions. Responsibilities included the development of the kinetic routines for the toxic chemical component of the model from those used in EXAMS II, TOXIWASP and WASTOX, integration of the WASTOX steady-state solution into WASP and providing technical assistance on all other components of model development.

Ecological Risk/Natural Resource Damage Assessments

Development of Water Quality Criteria for Wildlife

Client: U. S. Environmental Protection Agency

Principal investigator for the development of methodologies to determine water concentrations protective of aquatic feeding wildlife. Defined methods to relate laboratory toxicity estimates to wildlife species. Efforts included compilation and analysis of toxicity data, development of models to permit extrapolation of laboratory toxicity data to field animals and development of models of the relationship between water column contaminant concentrations and effects in wildlife. Initial work focused on dieldrin and DDT.

Modeling PCBs in the Aquatic Biota of Green Bay

Client: U.S. Environmental Protection Agency

Principal investigator for the development and application of a model of PCBs in the food web of Green Bay. This work is part of the Green Bay Mass Balance Study for the U.S. Environmental Protection Agency. The purpose of these studies was to evaluate the impacts of potential remediation alternatives.

Analysis of PCBs and Metals Contamination in the Biota of New Bedford Harbor, Massachusetts

Client: U.S. Environmental Protection Agency, Region I, Battelle Ocean Sciences

Project manager in charge of developing a mathematical model of the contamination of the lobster and winter flounder and their food chains in New Bedford Harbor and Buzzards Bay. Responsible for linking this model with a hydrodynamic-contaminant fate model developed by Battelle Northwest to project the response of the biota to various remedial action alternatives. This work was part of an EPA Superfund project in New Bedford Harbor.

Analysis of PCBs in the Hudson River Striped Bass and its Food Chain

Client: Hudson River Foundation, New York, NY

Project manager in charge of the development of a mathematical model describing the accumulation of PCBs in the striped bass food chain.

Analysis of Kepone Accumulation in the Striped Bass Food Web of the James River Estuary

Client: U.S. Environmental Protection Agency, Gulf Breeze, Florida

Project manager in charge of the development and application of a mathematical model describing the accumulation of the pesticide Kepone in the striped bass food chain. Projected the response of the food chain to declining exposure concentrations.

Pathogen Fate and Transport

Development of a Framework for Predicting the Fate of Genetically Engineered Microorganisms in Surface Water Systems

Client: U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, Florida

Principal investigator for the development of a model of the population dynamics of bacteria, phytoplankton and zooplankton in surface waters and application of this model to predicting the risk associated with the introduction of genetically engineered bacteria to these environments. Population dynamics models were developed for the Delaware River and Mirror Lake.

Modeling Fate and Transport of Pathogenic Organisms in Mamala Bay, Hawaii

Client: Mamala Bay Study Commission

Principal investigator for review of historical data, design of a sampling program and development and calibration of a mathematical model of pathogen fate in Mamala Bay. Goal is to determine pathogen sources and level of control necessary to meet water quality goals.

Evaluation of Cryptosporidium Sources and Fate in Milwaukee, Wisconsin

Client: Sara Lee Corporation

Principal investigator for the evaluation of the likely contribution of various potential sources to the Cryptosporidium responsible for a disease outbreak in the city of Milwaukee.

Hydraulic Engineering

Hydraulic Analysis of the Fairfield, New Jersey Sewer System

Client: Lee Purcell Associates, Inc.

Project engineer in charge of determining the capacity and flow characteristics of an in-place sewer system. Developed a gradually varied flow analysis for this purpose.

HONORS

Diplomate Environmental Engineer by Eminence, American Academy of Environmental Engineers, 2002
Manhattan College Environmental Engineering Alumni Club Service Award, 1994

PROFESSIONAL ACTIVITIES

Affiliations

American Academy of Environmental Engineers
Sigma Xi - The National Scientific Research Society
Society of Environmental Toxicology and Chemistry
American Society of Limnology and Oceanography
Water Environment Federation

Committees and Advisory Boards

2005	USEPA Science Advisory Board
1997	USEPA Technical Qualifications Board to review promotion application
1991-96	New York Water Environment Association Outstanding Paper Award Committee
1990-95	DuPont Technical Advisory Board for Evaluation of HMPA Releases at their Spurance Plant in Richmond, VA
1990	USEPA Exploratory Research Review Panel

Invited Participation in Technical Workshops

Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites. St. Louis, MO October 26-28, 2004 – Steering Committee Member.

SERDP/ESTCP Contaminated Sediments Workshop. Arlington, VA August 10-11, 2004.

Stability of Chemicals in Sediments. San Diego, CA April 8-10, 2003 – Steering Committee Member.

Sediment Stability Workshop. New Orleans, LA, January 22-24, 2002 – Steering Committee Member.

U.S. EPA Forum on Contaminated Sediments. Alexandria, VA, May 30-June 1, 2001.

National Research Council Workshop on Bioavailability. Washington, D.C., November 12, 1998.

SETAC Pellston Workshop: Re-evaluation of the State of the Science for Water Quality Criteria Development. Fairmont Hot Springs, MT, June 25-30, 1998.

National Academy of Sciences National Symposium on Contaminated Sediments. Washington, D.C., May 27-29, 1998.

SETAC Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection. Pensacola, FL, February 10-14, 1996.

California EPA Workshop on Critical Issues in Assessing Ecological Risk. Asilomar, CA, January 23-25, 1995.

USEPA Workshop on Taura Syndrome. Gulf Breeze, FL, August 2-3, 1994.

USEPA Workshop on Modeling Uncertainty. Buffalo, NY, February 3-5, 1991.

USEPA Workshop on Sediment Quality Criteria. Grosse Ile, MI, March 29-30, 1990.

Industry Sponsored Workshop on the Environmental Impacts of the Deicer Calcium-Magnesium-Acetate. Albany, NY, February 27, 1990.

USEPA Workshop on Biotechnology Risk Assessment. Breckenridge, CO, January 11-15, 1988.

SETAC Workshop on Risk Assessment. Breckenridge, CO, August 17-21, 1987.

PRESENTATIONS

Overview of the 2005 Grasse River Remedial Options Pilot Study. Fourth International Conference on Remediation of Contaminated Sediments, Savannah, GA, January 22-25, 2007.

Challenges to Monitoring and Assessing Natural Recovery. Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 27, 2005.

Monitoring to Support the Dredging Remedy on the Upper Hudson River. Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 26, 2005.

Adaptive Management as a Measured Response to the Uncertainty Problem. Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004

Optimal Use of Conceptual and Mathematical Models at Contaminated Sediment Sites. Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004

Sampling of Sediment and Water in the Upper Hudson River to Support the USEPA Dredging Remedy. Hudson River Environmental Society Conference, RPI, Troy, NY, October 5, 2004

Nature and Causes of Non-Particle Related Contaminant Releases in Large River Systems. Workshop on Environmental Stability of Chemicals in Sediments, San Diego, CA, April 10, 2003

Management of Contaminated Sediments. NSF US/Italy Workshop on Sediments, Arlington, VA, December 10, 2002

Use of Sound Science to Develop a Defensible Site Model. U.S. EPA Forum on Managing Contaminated Sediments, Alexandria, VA, May 31, 2001.

A Quantitative Framework for Evaluating Contaminated Sediment Sites. SETAC 20th Annual Meeting, Philadelphia, PA, November 14-18, 1999.

Prediction of Natural Recovery and the Impacts of Active Remediation in the Upper Hudson River. SETAC 20th Annual Meeting, Philadelphia, PA, November 14-18, 1999.

Evaluation of Remedial Alternatives for Contaminated Sediments: A Coherent Decision-Making Approach. National Research Council, National Symposium on Contaminated Sediments, Washington, D.C., May 28, 1998.

Applications of Models to the Risk Assessment Problem. Chesapeake Biological Laboratory, Solomans, MD, November 1, 1996.

Use of Food Web Models to Evaluate Bioaccumulation Data. National Sediment Bioaccumulation Conference, Bethesda, MD, September 11, 1996.

Assessment and Remediation of Contaminated Sediments at MGP Sites. Electric Power Research Institute, Monterey, CA, August 28, 1996.

Modeling the Environmental Fate and Transport of Metals. 26th Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection, Pensacola, FL, February 11, 1996.

Toxicologically Based Ecological Risk Assessment. California EPA Workshop on Critical Issues in Assessing Ecological Risk, Asilomar, CA, January 24, 1995.

Data Requirements for the Development and Use of Water Quality Models. USEPA Conference on Quality Assurance in Environmental Decision Making, IBM T.J. Watson Research Center, Yorktown Heights, NY, November 2, 1994.

Mathematical Modeling of the Bioaccumulation of Hydrophobic Organics. National Biological Survey, Columbia, MO, August 25, 1994.

A Model-Based Evaluation of PCB Bioaccumulation in Green Bay Walleye and Brown Trout. International Association for Great Lakes Research 36th Conference on Great Lakes Research, De Pere, WI, June 7, 1993.

Bioaccumulation Modeling of Micropollutants in the Field. International Workshop on Mechanisms of Uptake and Accumulation of Micropollutants, Veldhoven, The Netherlands, May 25, 1993.

Keynote Presentation. NIEHS Sponsored Workshop on the Bioaccumulation of Hydrophobic Organic Chemicals in Aquatic Organisms, June 29, 1992.

Modeling the Role of Bacteria in Carbon Cycling. Gordon Research Conference, New Hampton, New Hampshire, June 17, 1992.

Calcium Magnesium Acetate Biodegradation and its Impact on Surface Waters. Symposium on the Environmental Impact of Highway Deicing, University of California, Davis, October 13, 1989.

Food Chain Modeling in the Green Bay Mass Balance Study. International Association for Great Lakes Research 32nd Conference on Great Lakes Research, Madison, WI, June 2, 1989.

Modeling the Fate of Bacteria in Aquatic Systems. American Society for Microbiology Annual Conference, New Orleans, LA, May 18, 1989.

Application of a Food Chain Model to Evaluate Remedial Alternatives for PCB-Contaminated Sediments in New Bedford Harbor, MA, Superfund '88, Washington, D.C., November 29, 1988.

Modeling the Accumulation of Organic Chemicals in Aquatic Animals. Joint USA/USSR Symposium: Fate of Pesticides and Chemicals in the Environment, The University of Iowa, Iowa City, IA, November 15, 1987.

Modeling Kepone in the Striped Bass Food Chain of the James River. Virginia State Water Control Board, Richmond, VA, August 15, 1983.

Predicting the Effects of Toxic Chemicals in Natural Water Systems. U.S. Environmental Protection Agency, Environmental Research Lab, Athens, GA, November 3, 1982.

Modeling Toxic Substances in Aquatic Food Chains. Clarkson College Environmental Engineering Graduate Program, Potsdam, NY, October 29, 1982.

Predicting the Effects of Toxic Chemicals in Natural Water Systems. U.S. Environmental Protection Agency, Environmental Research Lab, Gulf Breeze, FL, September 13, 1982.

Modeling of Fate of Toxic Chemicals in Aquatic Systems. U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C., March 16, 1982.

PUBLICATIONS

Comment on "The Long-Term Fate of Polychlorinated Biphenyls in San Francisco Bay, (USA)". Connolly, J.P., C.K. Ziegler, E.M. Lamoureux, J.A. Benaman and D. Opydke, *Envion. Toxicol. Chem.* 24:2397-2398, 2005.

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A model of p,p'-DDE and total PCB bioaccumulation in birds from the Southern California Bight. Glaser D, J.P. Connolly, *Continental Shelf Research* 22:1079-1100, 2002.

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Modeling of Flood and Long-Term Sediment Transport Dynamics in Thompson Island Pool, Upper Hudson River. Ziegler, C.K., P. Israelsson and J.P. Connolly, *Water Quality and Ecosystem Modeling* 1:193-222, 2000.

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Modeling Carbon Utilization by Bacteria in Natural Water Systems. Connolly, J.P., R.B. Coffin and R.E. Landeck. In: *Modeling the Metrobolic and Physiologic Activities of Microorganisms,* C. Hurst, ed., John Wiley & Sons, Inc., 1991.

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WASTOX, A Framework for Modeling Toxic Chemicals in Aquatic Systems. Connolly, J.P. and R.P. Winfield, U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA 600/3-84-077, 1984.

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Calculated Contribution of Surface Microlayer PCB to Contamination of the Lake Michigan Lake Trout. Connolly, J.P. and R.V. Thomann, *J. Great Lakes Research* 8(2):367-375, 1982.

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The Effect of Concentration of Adsorbing Solids on the Partition Coefficient. O'Connor, D.J. and J.P. Connolly, *Water Research* 14(10):1517-1523, 1980.

APPENDIX B
Trace Elements in the Environment

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APPENDIX B

TRACE ELEMENTS IN THE ENVIRONMENT

As discussed in Section 2.4 of this report, the plaintiffs' consultants Drs. J. Berton Fisher and Roger Olsen used trace elements present in poultry litter to estimate the contribution of poultry litter to phosphorus in the Illinois River Watershed and Lake Tenkiller. However, the elements used are poor tracers. As presented in Section 2.4, the relative proportions of phosphorus (P) to zinc (Zn), copper (Cu), and arsenic (As) vary among the different media sampled by Dr. Olsen in the Illinois River Watershed. This is expected given the differing properties of the media and the different leaching rates and fate and transport properties of these chemicals. Additionally, the multiple sources of these chemicals further confound their use as tracers of a source material.

P, Zn, Cu, and As have differing chemical properties. P is a highly reactive, relatively insoluble non-metal that is one of the key elements required for life (Brady 1974). Zn and Cu are transition metals essential for plant and animal metabolism. However, Zn only has one significant oxidation state (Zn^{2+}) and is more soluble than copper. Copper can occur in solution as either Cu^{2+} or Cu^{1+} and readily complexes with many different ligands. Arsenic is a metalloid element that can be present in several oxidation states and thus has fairly complex chemistry (Hem 1985).

As described in Section 2.3 of this report, the divergent transport pathways these chemicals take once leached from poultry litter depends not just on their properties but on the pH, organic matter content, and other properties of the soil to which the poultry litter was applied (Arias et al. 2005). Arsenic is more mobile than zinc and copper (Gupta and Charles 1999). Zinc is more soluble than copper, but copper has a high affinity for dissolved organic matter (DOM) and thus has been shown to be transported farther with high concentrations of DOM (Impellitteri et al. 2002). Phosphorus, particularly in phosphate form, will adsorb to calcium-, iron-, or aluminum-containing soil particles. As these particles are transported from the watershed soils to sediments, some phosphorus forms will continually exchange into the water column, depending upon water column concentrations, and become available for biological consumption. While this is also true of copper and zinc, the rate and extent that they exchange between soil particles and the water column is quite different, given the higher solubility of zinc, and the relative mobility of copper due to its affinity for DOM. The water chemistry of arsenate, the dominant form of dissolved arsenic in oxidized surface waters, is similar to that of phosphate (Faust and Aly 1981). However, arsenic differs from phosphorus in that it is a redox sensitive element [typically found as As(III) or As(V)] and it is not essential element for biological growth, and thus its fate and transport is expected to diverge from that of phosphorus moving from watershed soils to lake sediments (Hinkle and Polette 1999; Mucci et al. 2000; Linge and Oldham 2004)

The average and range of Cu, Zn, As, and P concentrations in (litter-applied land) LAL soils, Illinois River Watershed stream and lake sediments, Illinois River Watershed control soils, and stream sediments within the Ozarks Plateaus collected through the National Water Quality Assessment Program (NAWQA; Petersen et al. 1998) are provided in are provided in Table A-1. Mean and maximum values in LAL soils, Illinois River Watershed stream and lake sediments are generally higher than those in Illinois River Watershed control soils. As discussed in Section 2.7 of this report, the variability in soil and sediment phosphorus concentrations are controlled in part by the soil and sediment aluminum and iron content. Control soils had lower concentrations of iron and aluminum. Thus, the lower concentrations in control soils may be due in part to soil type and the limited range of sediment types represented due to small sample size. The Ozarks Plateaus Study included the collection of sediments from fourteen locations that represent the range of sediment types, land uses and basin sizes within the Study Unit, which includes the Illinois and six other river basins. As shown on Table A-1, the concentrations of phosphorus, zinc, iron, and arsenic in Illinois River Watershed soils and sediments fall within the range of these values measured within the Ozarks Plateaus. Given that these sediments were collected from a variety of land uses and sediment types, the range in concentrations are likely the result of various sources as well as differences in sediment type. This variability in ambient concentrations confounds the use of these elements as tracers of poultry litter.

Table B-1. Mean and range of P, Cu, Zn, and As in Illinois River Watershed soils, stream and lake sediments, control soils, and Ozarks Plateaus Study Unit.

		Number of Observations	Mean	Minimum	Maximum
Total Phosphorus (mg/kg)	Lake sediment	45	1019.3	119.5	2021.6
	Stream sediment	24	543.5	152.3	1776.3
	Litter-applied land soil	166	847.9	46.9	2116.1
	Control soil	15	233.0	86.7	449.9
	Ozarks Plateaus sediment	37	668.4	400.0	1400.0
Total Copper (mg/kg)	Lake sediment	51	12.4	1.3	25.3
	Stream sediment	24	18.5	1.3	248.8
	Litter-applied land soil	166	20.8	3.1	44.9
	Control soil	16	5.7	2.0	13.7
	Ozarks Plateaus sediment	37	20.4	9.0	66.0
Total Zinc (mg/kg)	Lake sediment	51	60.6	10.7	116.9
	Stream sediment	24	58.0	16.0	120.7
	Litter-applied land soil	166	35.0	8.6	130.1
	Control soil	16	21.5	12.2	35.5
	Ozarks Plateaus sediment	37.0	296.0	43.0	5600.0
Total Arsenic (mg/kg)	Lake sediment	51	7.1	1.6	13.7
	Stream sediment	24	5.2	1.3	12.8
	Litter-applied land soil	166	3.4	1.3	8.0
	Control soil	16	2.4	1.4	4.0
	Ozarks Plateaus sediment	37	7.5	2.9	26.0

Data sources: Plaintiff database, 11/21/08; Ozarks Plateaus Study Unit, USGS National Water Quality Assessment Program Data Warehouse Export, 07/16/2008 (Peterson et al. 1998).

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APPENDIX C
Base Flow Calculations

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APPENDIX C
BASE FLOW CALCULATIONS

The base flow separation model used here is derived from Eckhardt's (2005) recursive digital filter separation method. The use of digital filters for baseflow separation has been commonly applied in watershed analyses (Arnold et al. 1995; Arnold and Allen 1999) Because runoff causes high frequency variability of streamflow, low-pass filtering of the hydrograph can be used to identify base flow.

The total flow y at any time step k can be divided into base flow and runoff as:

$$y_k = b_k + f_k \tag{1}$$

where:

f	=	runoff; and
b	=	baseflow.

The general form of the one parameter filter model proposed by Eckhardt is

$$b_k = Ab_{k-1} + By_k \tag{2}$$

The coefficients A and B are expressed in terms of the rate of groundwater recession, a, and the long-term ratio of base flow to total flow, R

$$\begin{aligned} A &= \frac{(1-R)a}{1-aR} \\ B &= \frac{(1-a)R}{1-aR} \end{aligned} \tag{3}$$

The parameter a defines the change in base flow as flow recesses during dry weather periods:

$$b_k = ab_{k-1} \tag{4}$$

It is calculated from the regression of b_k and b_{k-1} during dry weather periods.

For a perennial stream with porous aquifers, Eckhardt recommends a value of R close to 0.80. Using a value of 0.85, the base flow (red) and total flow (black) hydrograph at Tahlequah is shown in Figure C-1. The results of this analysis applied to the 2004 to 2007 USGS flow record at Talequah indicates that approximately 80% of the days during the summer season (May – September) are base flow days (Figure C-2). A base flow day is defined as a day when at least 70% of the total flow is base flow (Tortorelli and Pickup 2006).

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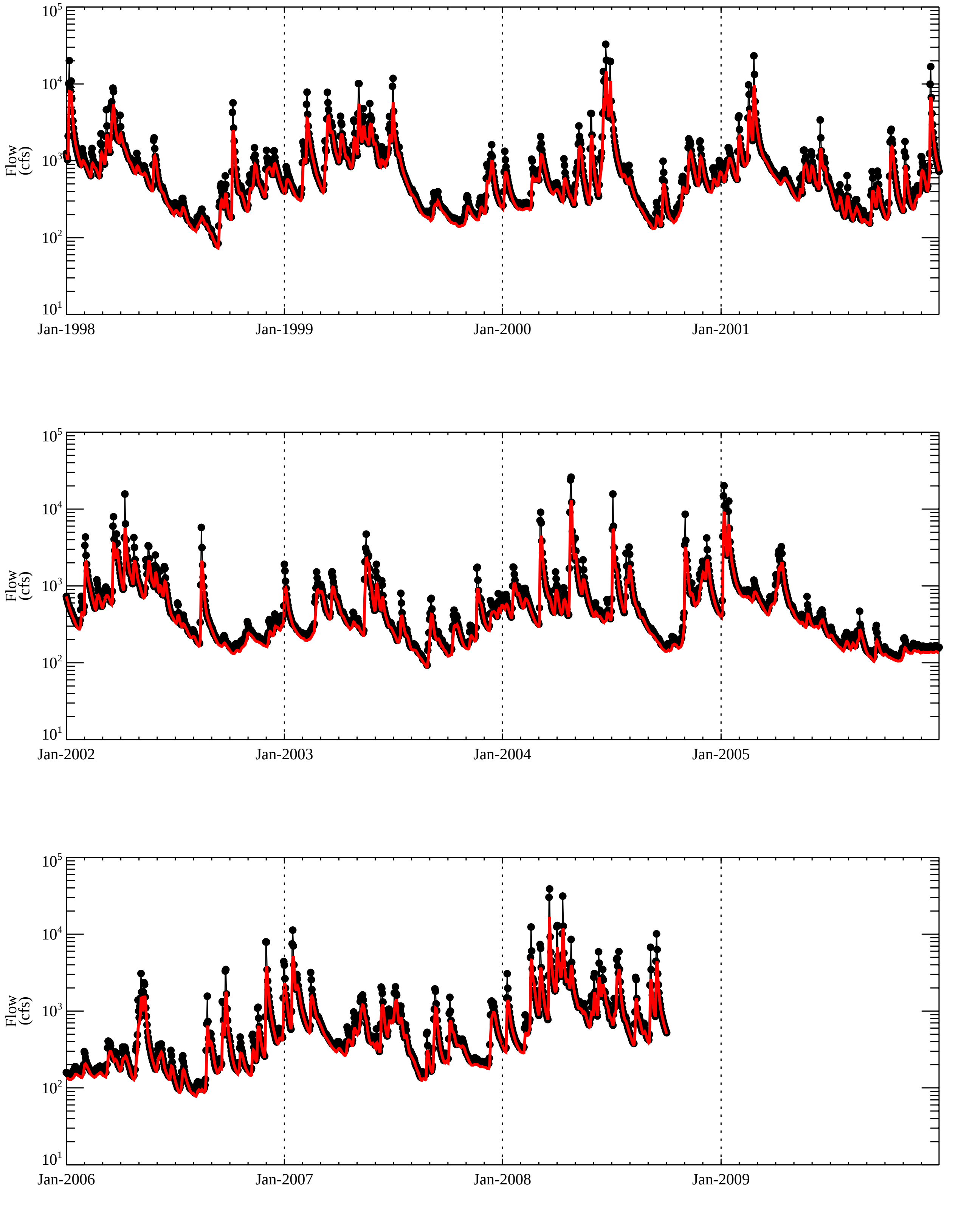

Figure C-1. Total and base flows at USGS station 07196500 at Tahlequah.
Data: USGS (1998 - present)

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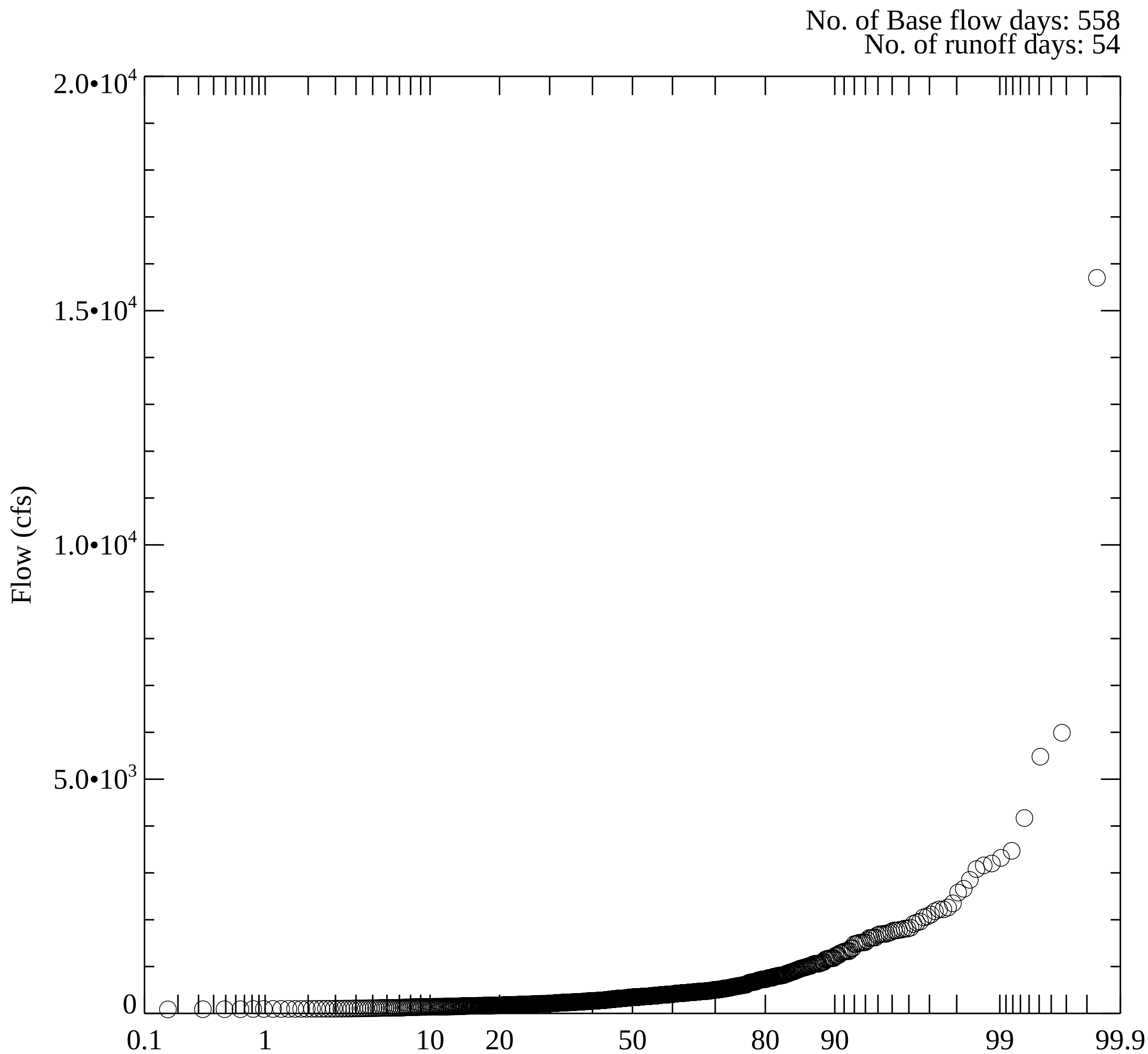

Figure C-2. Probability distribution of summer season flow at Tahlequah (2004-2007).

Data source: USGS (2004 - 2007).

APPENDIX D
Review of Potential Impact of Lake Frances

Quantitative Environmental Analysis, LLC
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APPENDIX D
LAKE FRANCES

Lake Frances is a run-of-the-river impoundment on the Illinois River located in Oklahoma, immediately downstream from the state line between Arkansas and Oklahoma. The lake was formed in 1931 with the construction of the Lake Frances dam. In 1977 the lake's surface area was measured at 2.31 km^2 with mean water depth of 1.8m and maximum water depth of 9.8m (United States Environmental Protection Agency [USEPA] 1977). By 1985, the mean depth had dropped to 1.2m with a maximum depth of 6.5m (Soballe and Threlkeld 1985) due to sedimentation of the lake. The Lake Frances dam was breached in 1990 during a flood event and one meter from the top of the spillway was lost. Consequently, the lake is now reduced to a two channel river and wetlands as shown in Figures D-1 and D-2.

Lake Frances has long been recognized as a sink for nutrients and in 1977 was considered eutrophic by the USEPA (USEPA 1997). In the USEAP study, the high loading rate of phosphorous of the Illinois River entering Lake Frances was attributed to wastewater discharges upstream. Lake Frances has a history of high nutrient concentrations and eutrophication between the 1970s until the dam breach in 1990. The primary sources of nutrients to the Illinois River during this time were upstream point sources (Soerens 2004). *released back into the water column.*

Several sources indicate that legacy phosphorus in the sediments may be currently contributing to the nutrient load in the Illinois River:

> *At the time of the dam collapse the lake had experienced a high degree of siltation with sediment levels being over 15 feet at the dam. All of the lake bed (approximately 560 acres) is now exposed with several hundred thousand cubic meters of nutrient-enriched sediment being subject to removal by river flow.* (Haraughty 1999)
>
> *This study showed the potential for bottom sediments in Lake Frances to increase phosphorus transport at the Illinois River, especially if the water column dissolved phosphorus concentration from Lake Frances decreases.* (Haggard and Soerens 2006).

In a study by Etta et al. (2006) evaluating impacts of wastewater treatment plant effluent discharges on dissolved phosphorus concentrations and sediment interactions in effluent-dominated Ozark streams (tributaries to the Illinois River in Arkansas), the researchers found:

> *…dilution-corrected SRP concentrations often increased after effluent P reductions, suggesting that legacy P stored within the stream reach was released back into the water column. Haggard et al. (2005) showed an internal P loading mechanism in an Ozark stream when effluent P concentrations were low (< 3 mg/L). Many other studies have shown that P-saturated wetland sediment release P to the water column when dissolved P concentrations are low (e.g. see Novak et al., 2004; Fisher and Reddy, 2001). It is not known how long P may be released from stream sediment back into the water column, maintaining elevated SRP concentrations.*

The State of Oklahoma, as represented by Mr. Derek Smithee, Chief of Water Quality for the Oklahoma Water Resources Board (Smithee Deposition 2008) is concerned that stored nutrients in Lake Frances may be impacting water quality downstream of Lake Frances. Mr. Smithee stated that he believes there are significant quantities of phosphorous and nitrogen stored in the current streambed and historical lake bed of Lake Frances and when the Lake Frances dam broke in 1990, nutrients released impacted the water quality in Lake Tenkiller.

During Mr. Smithee's recent deposition, Mr. Elrod asked about the deleterious impact on downstream water quality when the dam broke in 1990 due to stored nutrient releases (Smithee Deposition 2008). In response, Mr. Smithee clarified that the issue was:

> *nutrients that had been sequestered in the sediments over the decades would be released through re-channel cutting back into the river and thence to Lake Tenkiller, and because of this huge influx of nitrogen and phosphorous, the river and the lake would have significant algae problems…*

Asked if that concern became true, Mr. Smithee responded,

> *We did not see, over the long run, the data doesn't really show over the long run significant increases in algae in the river. Although the effect of that on the lake is, that is arguable.* (Lake referenced was clarified as Lake Tenkiller).

Asked if he had reached conclusion regarding the impact on Lake Tenkiller and if losing a dam at Lake Frances had an impact on Lake Tenkiller's phosphorous problems, Mr. Smithee responded:

Yes. (Smithee Deposition 2008)

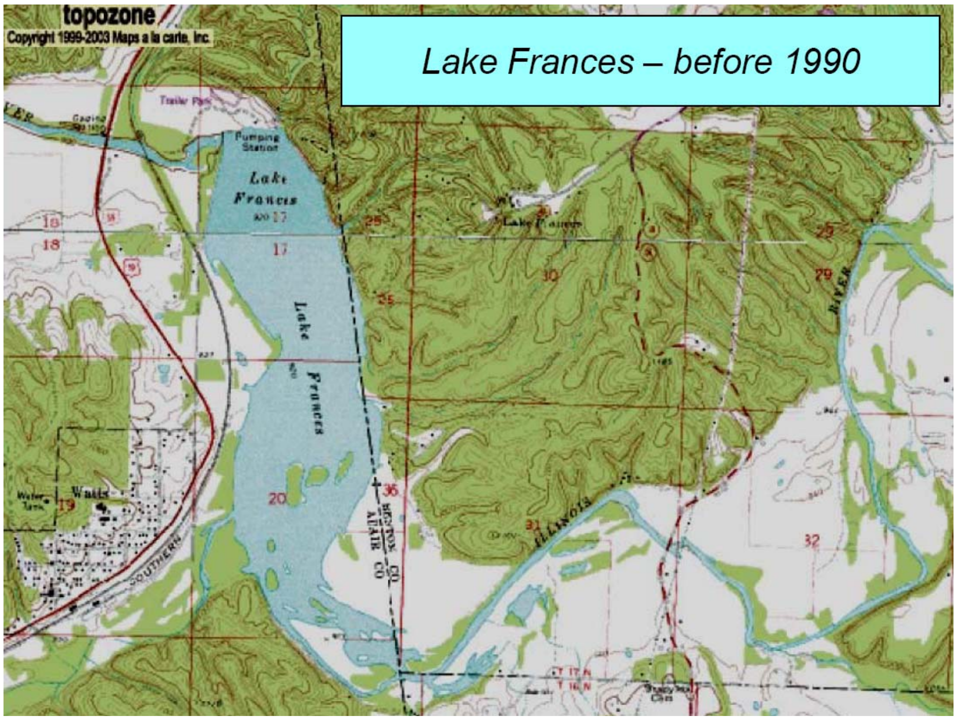

Figure D-1. Lake Frances before 1990 (Soerens 2004).

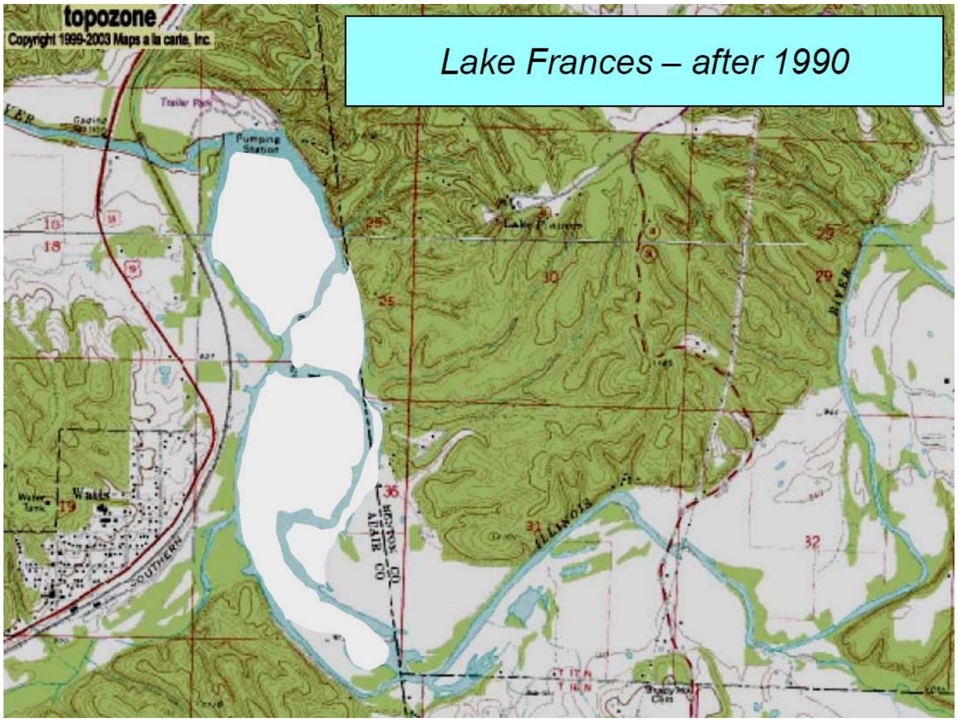

Figure D-2. Lake Frances after 1990 Dam Break (Soerens 2004)

Investigations into Lake Frances Contribution of Phosphorus Load to the Illinois River

The Illinois River near the Arkansas-Oklahoma state line is sampled by four different agencies (three in Arkansas, and one in Oklahoma) using different methods for sampling and load determination. In Arkansas, the Arkansas Department of Environmental Quality (ADEQ) takes grab samples every other month and calculates loads by averaging concentrations. The U.S. Geological Survey (USGS) takes composite samples 12 times per year and calculates loads using a regression model. Arkansas Water Resource Center (AWRC) takes grab samples every two weeks plus flow-weighted auto-sampler composite samples during all storm events and calculates loads by integration. In Oklahoma, regular samples are taken by the USGS in cooperation with the Oklahoma Water Resources Board (OWRB). Data collected is used by the OWRB to estimate phosphorus loads, yields, and mean flow-weighted concentrations for 3-year periods using a regression model.

Water quality monitoring in Arkansas of the Illinois River near Lake Frances is routinely done at Arkansas Highway 59 bridge crossing, upstream of Lake Frances. Routine monitoring in Oklahoma downstream of Lake Frances occurs at USGS gage 07195500. T. Soerens (2004) and others (Haggard and Soerens 2006; Parker et al. 1996) have attempted to compare loads upstream and downstream of Lake Frances to determine the contribution of Lake Frances on total phosphorus loads using the data from the various agencies. Figure D-3 illustrates one such comparison (Soerens 2004).

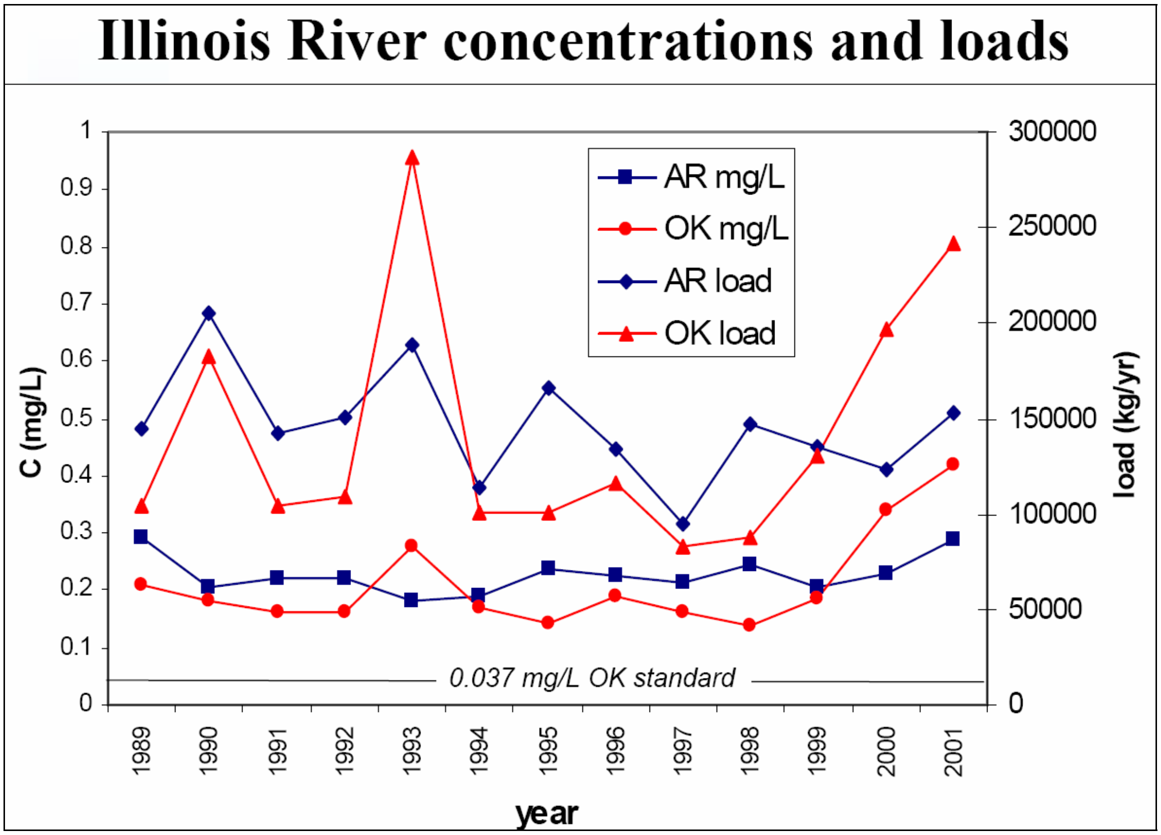

Figure D-3. Loads and Concentrations Upstream and Downstream of Lake Frances (Soerens 2004).

Soerens questioned if the difference between upstream and downstream loads is due to difference in the monitoring programs implemented by the various agencies or contributions from Lake Frances. The difference in the monitoring programs and how those differences influence the reported nutrient concentrations in the river does impact the load estimates. Prior to July 1999, only bi-monthly water quality samples were taken at the Oklahoma USGS site; whereas AWRC has been collecting grab samples every two weeks and flow-weighted storm composite samples since November 1996. Starting in July 1999, the USGS has collected surface runoff sample in addition to regular base flow samples at the Oklahoma USGS site.

The differences between upstream and downstream loads shown in Figure D-3 may be attributed to monitoring and load determination differences and/or contributions from Lake Frances due to resuspension of sediment or erosion of the exposed lake bed. Haggard and Soerens (2006) compared USGS data from both upstream and downstream locations in an effort to determine if Lake Frances sediments were contributing significantly to phosphorus concentrations in the Illinois River. The phosphorus concentrations measured during the years of 1997 – 2003 at both locations showed no significant difference between the upstream and downstream locations. However, because the water quality data taken by the USGS is not "paired" upstream and downstream of Lake Frances, Haggard and Soerens recommend that future monitoring efforts consider collecting water samples representative of the integrated stream cross-section that are "paired" during base flow and surface runoff conditions upstream and downstream of Lake Frances. When Haggard and Soerens ln-transformed the "paired" data from Parker et al. (1996) a significant difference was shown between upstream and downstream concentrations with the downstream being higher. Haggard and Soerens are concerned that legacy phosphorous in the bottom sediments may be released at rates significant enough to increased dissolved phosphorous concentrations in the Illinois River due to the internal phosphorous cycling at Lake Frances.

The State of Oklahoma has considered several studies to quantify the mass and impact of nutrients stored in the streambed and historic lake bed of Lake Frances on downstream water quality. However, as noted in Mr. Smithee's deposition (Smithee Deposition 2008), proposed studies focused on quantifying the mass of nutrient and/or erosion rates in or near Lake Frances have not been initiated due to a lack of funding.

Quantity and Transport Potential of Phosphorus from Lake Frances to Illinois River

Bounding calculations for phosphorus mass in the sediment and soil can be used to estimate the mass of phosphorus in the existing Lake Frances and associated wetlands. Maximum potential mass of phosphorus can be calculated by assuming the entire historic acreage of the lake (2.3 km^2) had an average siltation depth[1] of 3 m with an average phosphorus concentration of 740 mg/kg dry (average of two measurements taken in 2005 reported in AG database within Lake Frances, SD005A and SD005B locations). Assuming a dry bulk density of the soil of 1.4 kg/m^3 (Sauer and Logsdon 2002), the maximum mass of phosphorus in Lake Frances wetlands and river is approximately 7200 kg.

A low end estimate of the mass of phosphorus contained in the sediment and soils of Lake Frances and associated wetlands can be calculated from assuming a lower siltation depth of 1 m, yielding a mass of 2400 kg of phosphorus in the soils and sediments of the historic 2.3 km^2 lake. These estimates provide an upper and lower bound of the mass of phosphorus potentially contained in the soils and sediments that could be released into the Illinois River through natural flux from the sediment into the water column, erosion of the river banks, and loss of sediment and soil during storm events.

Phosphorus transport rates from the lake sediments to the water column can be determined from release rates measured by Haggard and Soerens (2006) from Lake Frances sediments. Under aerobic conditions, sediment phosphorus release rate was measured at approximately 4 mg m^{-2} day^{-1} and 15 mg m^{-2} day^{-1} under anaerobic conditions. Combined with the surface area at the sediment water interface, a transport rate of phosphorus to the water column can be calculated. Assuming the current surface area of Lake Frances (0.34 km^2 as determined from length and width measurements, GoogleEarth 2008), the phosphorus transport from the sediments is approximately 500 kg/year for aerobic condition release and 1900 kg/yr under anaerobic conditions. These loads are minor compared to the estimated loads entering Lake Frances between 1989 and 2001, which ranged between 100,000 kg/yr and 200,000 kg/yr (Soerens 2004).

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[1] The mean 3 m siltation depth was estimated based the reported 15 ft of siltation at the dam prior to the dam breach in 1990 and the mean depth of the lake in 1985 at 1.2 m with a maximum depth of 6.5 m. In 1977 the mean depth was reported as 1.8 m with a maximum depth of 9.8m (United States Environmental Protection Agency, 1977). The 3 m siltation depth represents a probable high end of siltation based on the 15 ft (4.5m) reported at the dam in 1990 and the maximum depth decrease between 1985 and 1977 of 3.3 m, while the mean depth for the entire water body decreased 0.6 m between 1985 and 1977.

Using Harggard and Soerens phosphorus release rates for the entire wetlands and lake area (2.3 km^2), approximately 3400 kg/yr phosphorus may be released from the sediments under aerobic conditions. Based on an approximate average of 145,000 kg/yr entering Lake Frances (Soerens 2004), Lake Frances wetlands could contribute as much as 2 - 3% additional load to the Illinois River if the wetlands were thoroughly saturated and runoff was sufficient to transport the wetland waters to the river. Additional transport mechanisms for phosphorus from the sediments and soils of current and historic Lake Frances include river bank erosion and sediment transport from overland flow and resuspension of sediments during storm flows.

Even with these load estimates, the question remains if there is enough nutrient mass and nutrient release from Lake Frances to impact water quality in the Illinois River? Mr. Smithee was asked if he thought that the 0.0375 mg/L phosphorous standard could be met below Lake Frances if the incoming water had no phosphorous. Mr. Smithee would not speculate (Smithee Deposition 2008). Haggard and Soerens (2006) indicate they believe that bottom sediments in Lake Frances have the potential to release high amounts of phosphorus and to maintain phosphorus concentrations downstream in the Illinois River elevated above the 0.0375 mg/L phosphorus standard.

Conclusions

Lake Frances is likely to be contributing some amount of legacy phosphorus to the currently load in the Illinois River downstream of the lakebed through resuspension of sediment, release of phosphorus from the sediment and erosion. The State of Oklahoma should consider further characterization of the sediments and rate of erosion to quantify the Lake's contribution of phosphorus to the Illinois River.

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